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NIC-2610G-001-80

SOVIET WATCH OFFICER'S GUIDE

NISC

Prepared
by
NAVAL INTELLIGENCE SUPPORT CENTER
for
DIRECTOR OF
NAVAL INTELLIGENCE

GOVERNMENT USE ONLY

UNCLASSIFIED

NIC-2610T-001-80

DEPARTMENT OF THE NAVY
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SOVIET WATCH OFFICER'S GUIDE

SPRAVOCHNIK VAKHTENNOGO OFITSERA

NISC

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MILITARY PUBLISHING HOUSE OF THE MINISTRY OF DEFENSE OF THE USSR, MOSCOW, 1975

CHAPTER 1

DUTIES OF THE OFFICER OF THE WATCH /9*

Section 1.1. General Duties

The officer of the watch is in charge of the ship's watch section. Ship personnel, other than individuals to whom the officer of the watch is subordinate, shall execute all orders of the watch officer.

The duties of watch officer, when the ship is underway or at anchor, are performed by personnel authorized by order of the Commanding Officer, after evaluating their skills against the requirements of a special program.

The following personnel are subordinate to the officer of the watch:

a) personnel of control and battle stations in a state of combat readiness and in matters relating to shiphandling, lookout, and use of weapons;

b) the ship's watch detail, duty section, and guard detail (if a ship Officer of the Deck has not been designated).

The officer of the watch shall:

a) in the execution of his duties be guided by station bills and other documents specifying the combat and daily routine activity of the ship;

b) maintain the prescribed combat readiness of the ship;

c) take charge of the watch section and supervise the performance of routine duties by personnel by paying special attention to ensuring vigilant performance of duty by signalmen and lookouts;

d) ensure safety of the ship and take measures to prevent accidents;

e) be familiar with the condition of visual communication and lookout equipment, know how to use it and how to employ recognition signals properly;

f) sound alarms (on order or by acting independently);

g) be familiar with the condition of the main power plant; /10

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* Numbers in the right margin indicate pagination in the original text.

h) be responsible for the proper operation of machinery and equipment located on the main deck;

i) make certain that rescue equipment is in the constant state of readiness;

j) require all personnel to observe ship regulations, wear the proper uniform, and maintain order and cleanliness on the main deck and near the sides of the ship;

k) issue orders and signals in accordance with the plan of the day and see that they are carried out;

l) salute officials arriving aboard ship and render proper salutes when meeting or passing other ships;

m) keep a deck log during the watch and sign it on being relieved.

The officer of the watch must be able to direct damage control operations. In the event of fire, flooding of a compartment, dangerous concentrations of gases, or increased radiation levels, he immediately sounds the emergency alarm, takes damage control measures and reports to the Commanding Officer and the ship's Officer of the Deck.

The officer of the watch must know what measures to take in the event of the onset of colder weather, the approach of cyclones (typhoons, hurricanes) and the encountering of fog.

If necessary, the officer of the watch has the right to request, both day and night, permission from the Commanding Officer of the ship or Executive Officer to go aloft. The form of the request is as follows: "Comrade Captain Second Rank, permission is requested to go aloft." In situations which do not permit delays, the officer of the watch must act independently, informing the ship's Commanding Officer and others of the situation involved as soon as possible.

The officer of the watch must not be distracted by any extraneous activities which bear no relation to the execution of his duties.

The officer of the watch must be equipped with binoculars, a whistle, and a megaphone. In addition, he must carry a notebook and pencil.

In the event of alarm the officer of the watch turns over his duties to the ship's Executive Officer and assumes his post according to the station bill.

Upon being relieved of the watch, the officer of the watch must furnish information regarding: /11

a) the prescribed combat readiness of the ship;

b) the ship's position (by naming the place and marking it on the chart);

c) recognition signals;

d) operating machinery;

e) the condition and operating modes of the lookout equipment;

f) the location of the ship's Commanding Officer and Executive Officer as well as the location of the Commander of the formation and the Chief of Staff;

g) . orders and instructions issued for the watch by the ship's Commanding Officer or by the Commander of the formation;

h) exercises, drills, and activities conducted aboard ship;

i) protective equipment against weapons of mass destruction;

j) the condition and operating modes of the propulsion power plant, of the storage battery compartment and central ventilating systems, and the time of the last ventilation of the battery compartment;

k) the radiation level aboard ship and the established procedure for monitoring uninhabited spaces (or compartments).

The officer of the watch (Officer of the Deck) may issue orders concerning all personnel of the ship or her subdivisions over the general announcing system. In issuing commands over the general announcing system the immediate situation should be taken into account and no orders should be given which might reveal the organization or activity of the ship.

The general announcing system may be used by the Commanding Officer of the ship, his Executive Officers, his Deputy for political affairs, the officer of the watch (Officer of the Deck), the officer on duty below decks, and the head of the engineering department (on a submarine).

Section 1.2. Duties Underway

The officer of the watch is subordinate to the Commanding Officer of the ship and to the Executive Officer when the latter, acting for the Commanding Officer, is on the bridge.

No one aside from the above officers and their immediate superiors has a right to interfere with the orders issued by the officer /12

of the watch.

The officer of the watch is directly subordinate to the Commanding Officer of the ship or to the Executive Officer in matters relating to maneuvering, the use of weapons in the event of sudden encounters with the enemy, evasion of attacks by submarines, aircraft, helicopters, and torpedo boats, including evasion of missiles, torpedoes, and mines.

The officer of the watch shall:

a) ensure the proper maintenance of the prescribed course, speed, and station of the ship in order, as well as the depth, operating conditions and the mode of propulsion of a submarine;

b) monitor the plotting of the ship's course by periodically determining her position;

c) note changes in bearing when meeting ships at sea;

d) see that the running lights are operating properly and, when navigating without lights, make certain that the ship is completely darkened;

e) take measures to eliminate the emission of smoke, sparks, and flames from stacks, should they occur;

f) supervise the hoisting of signals when making changes in course, speed, or when executing maneuvers;

g) report to the Commanding Officer (or to the Executive Officer) on everything observed that might affect the safety of navigation or the performance of the assigned mission, including changes in the situation and navigation conditions;

h) alert the head of the engineering department one-half hour prior to the arrival of the ship at its destination (such as anchorage, narrows, etc.), and in other instances when deemed necessary.

The Commanding Officer of the ship sets the course and speed of the ship--and, on a submarine, the depth--through the officer of the watch.

The officer of the watch has the right to change the course and speed of the ship (and the depth on a submarine) without permission from the Commanding Officer only if the safety of the ship is in danger; for example, to avoid collision with another ship, upon detection of a sudden navigational hazard, to evade sudden attacks by the enemy, or to rescue a man overboard.

On submarines navigating submerged, the officer of the watch /13

shall:

a) maintain a 360° periscope lookout when the submarine is operating at periscope depth;

b) monitor the trim, buoyancy, depth below the keel and depth of the submarine, and adjust the trim, if necessary;

c) monitor the condition of the main power plant, the radiation level, the electrolyte density and battery voltage, the hydrogen content in percent and the concentration of gases, and report this to the Commanding Officer;

d) regulate the movement of personnel between compartments and maintain quiet and order within;

When the submarine is lying on the sea bottom or is anchored underwater the officer of the watch shall:

a) observe the readings of the depth gauge and trim indicator;

b) make certain that the air regeneration system is in good working condition and that the air distribution is proper; and

c) make sure that the pressure hull is watertight and the battery wells, bilges and spaces are always dry.

When the ship is underway the officer of the watch must remain on the bridge at all times. Officers of the watch are relieved (or relieved temporarily) by permission of the Commanding Officer of the ship (or the Executive Officer).

In addition to the rules given under the general duties above the officer of the watch underway shall, upon being relieved of his watch, provide information concerning:

a) the position of the ship (observed or calculated), course according to the gyroscopic or magnetic compasses, and the time of change in course, the speed, the nature of the formation or its number, and the station of the ship in formation;

b) conditions in the area of navigation, i.e. beacons, markers, lookout stations, depth, current, approaching ships or ships being overtaken, etc.; and

c) machinery and equipment used in propelling and handling the ship, as well as the time of inspection of the surface propulsion units and the battery electrolyte density and voltage. /14

The incoming officer of the watch must personally check the position, course, speed and station of the ship in order.

When the watch is relieved on submarines additional information is furnished regarding the operating depth submerged; operating mode; how the submarine answers the planes; visibility range of the periscope; hydrologic data and the time they were last taken; the radiation level and gas content of the air; the condition of special air regeneration instruments and equipment; the position of the submarine; the condition of the negative tank; the condition of the battery and ship ventilating systems; and the procedure for releasing personnel to the bridge.

Section 1.3. Duties While the Ship is at Anchor or Moored

When the ship is at anchor (moored to a buoy or bow-and-stern) the officer of the watch is subordinate to the Executive Officer (Officer of the Deck). No one, except the Executive Officer (Officer of the Deck) and his immediate superiors, may interfere with the orders given by the officer of the watch.

The officer of the watch shall:

a) report to the Officer of the Deck on everything observed that could affect the safety of anchorage;

b) insure proper use of the ship's launches and boats, supervise their dispatching and return, and embark personnel in them, making certain they are not loaded beyond capacity;

c) insure the observance of harbor and port regulations by personnel of the ship and passing launches and boats;

d) take measures to insure safe mooring and movement of boats and launches alongside the ship;

e) take measures to render assistance to boats in distress and to rescue those who are in danger of drowning;

f) submit a morning report to the Executive Officer one-half hour before colors;

g) assure that ship's bells are sounded at the proper time. /15

The officer of the watch looks after the anchor chain and its scope, making sure the latter meets the anchorage and weather conditions requirements. He also looks after mooring lines and clearing away of the second anchor.

If the wind freshens he orders wind measurement reports every hour or one-half hour, depending on the situation, and takes measures to recover boats and launches or directs them to a sheltered anchorage.

The officer of the watch shall pay particular attention to the drift of the ship. He shall monitor it by using either a drift lead put over the side, natural range lines or landmarks.

The officer of the watch is responsible for making the ship ready to receive supply ships on time (i.e., responsible for stowing ladders, boats, davits, and cranes), for the rapid recovery of mooring lines and arranging the taking on of supplies so that the supply vessels spend the least amount of time alongside the ship.

Before testing the engines the officer of the watch takes precautionary measures with respect to the boats (and launches) and the lines astern; he watches the mooring lines and anchor chain. When he is positive that the engine order telegraph is ready he authorizes, with the knowledge of the Executive Officer, to start testing the engines.

During anchorage, the officer of the watch must be on the main deck, preferably on the quarterdeck or at the accommodation ladder. In cold weather when the ship is anchored with steam up, during jacking over the engines, and in other situations requiring personal supervision of the surrounding area, and on submarines, the officer of the watch shall be on the bridge.

In addition to duties mentioned in Section 1.1. the officer of the watch, at the time of relieving the watch when the ship is at anchor, must furnish information regarding:

a) readiness of the ship to get underway;

b) trim of the submarine and its readiness to dive;

c) scope of anchor chain in the hawse (moored to a buoy by a hawser or to a pier);

d) clearing away of the second anchor;

e) depth, sea bottom, and current; /16

f) crew members absent and the presence of noncrew members aboard ship;

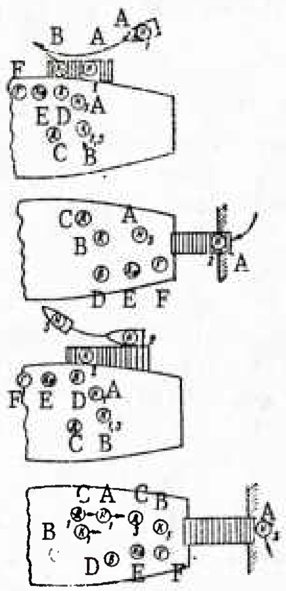
g) launches and boats, both away from the ship and alongside;

h) disposition of ships anchored in the roadstead and the location of the senior officer present; and

i) conventional alarm signals.

The officer of the watch controls the movement of all personnel and articles to and from the ship.

When receiving launches carrying high-ranking officials, the officer of the watch occupies the position indicated in Fig. 1.1.



Legend: /17

(A) High-ranking official
(B) Commanding Officer of the ship
(C) Officer of the Deck
(D) Officer of the watch
(E) Petty officer of the watch
(F) Bugler

Arrival:

1 - moment at which the signal "pipe the side" is given
2 - moment at which the command "attention" is given
3 - moment at which the report is given

Departure:

1 - the moment the official arrives on the main deck, the command "attention" is given
2 - the side is piped the moment the launch departs
3 - the command "at ease" is given the moment the "execute" signal is given

1. If the official is received (or escorted) only by the officer of the watch or the Officer of the Deck, the latter occupies the position of the Commanding Officer of the ship. Otherwise the procedure for arrival (and departure) remains the same.

2. The numbers next to the designations for officials indicate the position of these officials at various moments during the arrival. The absence of numbers next to the designations indicates that these individuals do not change positions during the arrival (or departure).

Fig. 1.1. Schematic diagram showing the position of the duty section and watch detail personnel during the arrival and departure of high-ranking officials

When receiving launches (boats) carrying petty officers and seamen, the officer of the watch stands at the top of the ladder until the last man leaves the launch (boat).

Whenever personnel disembark from the ship the officer of the watch shall not permit the men to congregate near the ladders (or gangways). Before disembarking or going on liberty, departing petty officers and seamen must be in formation.

As the launch (boat) approaches the ladder, the officer of the watch directs the seamen and petty officers to embark first, followed by the officers, making sure that the launch is not loaded beyond capacity.

During the embarkation of personnel in launches (boats) and before their departure from alongside the ship, the officer of the watch remains at the top of the ladder.

Launches (boats) may pull away from the ship only on order of the Commanding Officer or the Executive Officer, his Deputy for political affairs, or the officer of the watch (Officer of the Deck).

When departing the ship, launches (and boats) must be fully supplied with the equipment, as prescribed.

Whenever a launch or boat is dispatched the officer of the watch will insure:

a) when dispatching a boat, the presence of a full complement of oarsmen, signal equipment, a lantern, and rescue equipment;

b) when dispatching a launch, sufficient supply of fuel, water, and firefighting equipment, in addition to the items mentioned above, as well as proper functioning of the running lights.

When dispatching a launch (or boat) beyond the limits of the harbor or roadstead the officer of the watch must make certain that a compass and a chart (or a diagram) of the area of navigation are on board.

If there are officers on board, the coxswain of the launch (or boat) pulls away on order of the senior officer present. /18

All officers--except Executive Officers and the Commanding Officer's Deputy for political affairs, Commanding Officers of warships of all classes, and high-ranking officials--must obtain permission from the officer of the watch before giving orders to shove off.

If a high-ranking official is escorting those who are departing, permission to shove off must be obtained from him.

When petty officers and seamen leave the ship the coxswain of the launch (or boat) pulls away from the side of the ship on order or with permission of the officer of the watch.

Launches (or boats) must not remain needlessly near ladders. They are either hauled out to the boat booms, attached to the guess rope, or, if there is no special order, kept in the water abeam. A boat must be secured to the guess rope when at least two oarsmen and a helmsman are on board.

During anchorage in roadsteads at night, and with the onset of colder weather, launches (and boats) must be hoisted aboard ship or sent to harbors (i.e., sheltered places of anchorage).

During anchorage in enclosed bays and harbors when it is dark, only those boats which are absolutely needed are permitted to remain in the water; the officer of the watch must keep a constant watch over them and see that the boats are made fast.

Section 1.4. The Officer of the Watch, the Navigator and the Combat Information Center (CIC)

Before taking over the watch the officer of the watch must obtain information from the navigator on the following: the position of the ship and the accuracy with which the position was determined and the information concerning navigation conditions during the forthcoming watch (the course of the ship according to the preliminary plotting, any nearby navigational hazards and their markings). Together with the navigator he should mark control and danger bearings, distances, depths, leading lines (see Section 7.5.) and record the basic data.

The officer of the watch receives the following information from the navigator:

- reference data of navigational and hydrometeorological nature in the area of navigation;

- the time the ship will approach a combat training area, a narrow channel, an approach buoy, or a point of rendezvous, and the time she will leave the training area, the fairway or the narrow channel, as well as the data for insuring navigational safety (such as control and danger bearings, distances, depths, etc.); /19

- the new course, the estimated time for turning, and the control bearing (or distance) to the reference point five minutes and one minute before turning;

- the moment of turning onto the new course;

- corrections for major navigation instruments;

- the computed data on movement of oncoming vessels and suggestions for passing them;

- the time for switching on, switching off, or switching over of the degaussing gear;

- the time of the rising and setting of the sun and moon and the beginning and end of nautical and civil twilight.

The officer of the watch informs the navigator about the following:

- changes in the course and speed of the ship;

- the beginning and end of the turn onto a new course;

- orders received about the station change of his ship in the formation or about the relocation to another formation;

- the detection of targets which may interfere with the planned maneuvers the ship will perform;

- the appearance or disappearance from the sight of shores, navigational aids, and other objects important in navigation;

- sharp changes in weather conditions (decrease in visibility, freshening of the wind, etc.);

- changes in the operating depth of a submarine.

After receiving permission from the Commanding Officer of the ship to give commands directly to the helmsman (when navigating with the aid of ranges, in narrow channels, when approaching a given point for anchorage, etc.), the navigator informs the officer of the watch of the permission and informs him of each command given to the helmsman.

The officer of the watch is personally responsible for supervising watchstanding by radarmen in the Combat Information Center (CIC) by way of periodic inspection of the horizon on the PPI repeater.

The officer of the watch must keep the CIC Officer constantly /20
posted on the situation and its possible changes, pointing out the most important targets that must be kept under observation.

The officer of the watch receives from the CIC Officer information on the following:

- any detected targets and their coordinates;

- the classification of targets and results of their identification;

- target motion parameters and their changes;

- results of the analysis of the situation.

On submarines, in addition to the above information, the officer of the watch receives from the CIC the following:

- data on hydrological conditions;

- radar observations;

- suggestions for selecting optimal operating depths and speed to insure the best conditions for using the sonar equipment and avoiding detection by the enemy.

Section 1.5. Duties of the Junior Officer of the Watch

The junior officer of the watch is appointed on surface ships of the first rank. He is the immediate assistant to the officer of the watch when the ship is underway and the immediate executor of his orders. By order of the Commanding Officer, a junior officer of the watch can also be appointed when the boat is at anchor (at a mooring buoy or pier).

The junior officer of the watch must be familiar with all the duties of the officer of the watch and be ready to take his place, if necessary.

When going on watch duty the junior officer of the watch must receive information about the following from his predecessor:

a) the course and position of the ship;

b) the station of the ship in formation;

c) the combat readiness of the ship;

d) the readiness of the lifeboats;

e) the work being done on the main deck;

f) the condition of hatches, access holes, and exits to the main deck; /21

g) the running lights;

h) the orders that have not been carried out; and

i) darkening of the ship main deck and superstructures when navigating without lights.

When dispatching a lifeboat while the ship is underway, the junior officer of the watch is responsible for her timely and proper lowering, and if so ordered, he embarks as the boat officer.

The junior watch officer must periodically check, either personally or through his subordinate battle station officers, the operation of the running lights.

The junior officer of the watch is located mainly on the bridge together with the watch officer.

Section 1.6. Relieving the Watch

The officer of the watch is in direct charge of the ship's watch.

Special watches in departments and divisions are under the command of immediate officers with the exception of personnel at control or battle stations in the state of combat readiness, who are under the command of the officer of the watch.

A normal watch is four hours in duration. Depending on the situation, the duration of watches at individual stations can, by order of the Commanding Officer of the ship, be reduced to one hour or increased up to six hours. At the helm and lookout stations the normal watch is two hours.

Fifteen minutes before a watch underway is relieved, the officer of the watch--or the Officer of the Deck if the ship is at anchor and a watch officer has not been assigned--will give the command: "Next watch prepare for duty. Uniform (such and such); for deck watch, number (so and so)."

When the ship is at anchor (or moored) those relieving the watch line up in ranks at quarters for inspection at the prescribed time on command from the watch.

The officer of the watch (Officer of the Deck) directs the general inspection of the watch.

Ten minutes before relieving the watch the officer of the watch (Officer of the Deck) gives the command: "Next watch on duty" or "Next watch line up in ranks at such and such a location." Five minutes /22
before relieving the watch the Officer of the Deck (Officer on duty on lower decks) gives the command: "Attention! Begin inspection!" He then begins to inspect the ship's watch. At the same time the engineer-

ing watch officer (officer on duty in the engineering department) proceeds to inspect the special watch.

When the ship is at anchor inspection of the watch is conducted in the following manner: the roll call of personnel entering the watch is conducted and their familiarity with their duties are checked. After receiving a report from the officer on duty in the engineering department concerning the results of the inspection, the officer of the watch (Officer of the Deck) gives the command: "Proceed to your regular stations," whereupon personnel run to their stations to relieve the watch.

Upon receiving reports from watch stations officers and from the officer on duty in the engineering department that the next watch has taken over, the officer of the watch gives the command: "Relieved personnel leave your stations." On this command the relieved personnel leave their stations and the new watch assumes the responsibilities of watch duty.

When the ship is underway the inspection of the watch is conducted in the following manner: the incoming watch engineer and the officer on duty on lower decks on a surface ship inspect the next watch of the engineering department, men on duty in the compartments, and the guard detail at stations specified by ship orders. There is no watch inspection on submarines.

In accordance with the announced state of combat readiness, personnel of the incoming watch, on the watch officer's command "Next watch on duty" check their watch stations and duties and report by telephone on the status of these stations to the control stations of the individual watches and, on a submarine, to the watch officer in the control room. When permission is granted, they take over the watch.

On submarines, after taking over a new watch, the engineering watch officer makes the rounds of compartments, checks the arrival of men on watch at duty stations and inspects their performance. He then reports all this to the officer of the watch.

CHAPTER 2

SEAWORTHINESS AND MANEUVERING PROPERTIES OF SHIPS*

Section 2.1. Buoyancy

Buoyancy is the ability of a ship to remain afloat with a given trim while carrying all loads necessary to execute combat missions typical of the given type of ship. /23

1. Forces Acting on a Ship

The following forces act on a ship lying dead in calm water:

- the forces of gravity acting on all parts of the ship and weight of all loads located thereon, the resultant of which is the force of gravity P applied at the center of gravity G of the ship and directed vertically downward (Fig. 2.1);

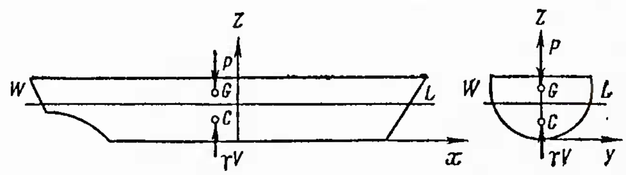


Fig. 2.1. Forces acting on a ship

- the hydrostatic forces due to water pressure acting on the submerged part of the ship hull, the resultant of which is the upward (buoyancy) force γV applied at the center of gravity of the submerged volume of the ship, called the center of buoyancy C, and directed vertically upward. /24

The force of gravity (weight) of the ship in Newtons is

$$P = gM, \tag{2.1}$$

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* In the formulas of this chapter, when using the SI System, force (weight) must be expressed in N (Newtons), the moment of force in N·m, and specific gravity γ in N/m^3; for calculations in the MKS system, force (weight) must be expressed in ton-force, moment of force in T(F)·m, and specific gravity γ in $T(F)/m^3$.

where g is the acceleration due to gravity (9.81 m/sec^2);

M is the mass of the ship, kg.

The mass M of the ship and the coordinates of the center of gravity G are:

$$\left.\begin{aligned} M &= \sum m_i; \\ x_g = \frac{1}{M}\sum m_i x_i; \quad & y_g = \frac{1}{M}\sum m_i y_i; \\ z_g &= \frac{1}{M}\sum m_i z_i. \end{aligned}\right\} \qquad (2.2)$$

where m_i, x_i, y_i and z_i is the mass of each individual load component of the ship and the coordinates of its center of gravity, respectively.

The buoyant force γV is determined primarily by the submerged volume V (displacement) of the ship. The specific gravity of water γ varies slightly, within 3%.

The volume displacement in m^3 is

$$V = \delta LBT \qquad (2.3)$$

where δ is the block coefficient (or the overall fullness coefficient);

L is the length of the ship along the designed waterline, m;

B is the beam of the ship at the designed waterline, m; and

T is the draft, m.

For certain types of ships the values of coefficient δ are: for cruisers, 0.45-0.60; destroyers, 0.44-0.53; and for launches, 0.54-0.55.

2. Conditions and Equations of Equilibrium

1) The force of gravity (weight) of a ship must be equal to the buoyant force

$$P = \gamma V \qquad (2.4)$$ /25

If $P > \gamma V$, the ship will submerge and if $P < \gamma V$, the ship will rise.

2) The center of gravity and the center of buoyancy must lie on the same vertical line:

$$y_c - y_g = (z_g - z_c) \tan \theta; \qquad (2.5)$$

$$x_c - x_g = (z_g - z_c) \tan \psi,$$

where x_c, y_c and z_c and x_g, y_g and z_g are the coordinates of the centers of buoyancy and gravity, m;

θ and ψ are the angles of heel and trim, degrees.

3. Reserve Buoyancy of Ships

Reserve buoyancy is the greatest possible buoyant force increase which is measured by a ship's watertight volume above the water (it specifies the greatest possible volume of water which the ship can accept within its hull and still remain afloat). The maintenance of the ship's reserve buoyancy is insured by the integrity and watertightness of its sides above the water and main deck.

In terms of volume and buoyant force the reserve buoyancy, expressed in percent, is

$$A = V_n - V; \quad A\gamma = \gamma (V_n - V);$$
$$\frac{V_n - V}{V} \cdot 100 \text{ or } \frac{A}{V} \cdot 100. \qquad (2.6)$$

where V_n is the volume of the hull up to the upper watertight deck, m^3;

V is the volume of the hull up to the effective waterline, m^3.

The reserve buoyancy of an undamaged ship is

$$A \approx S \cdot H \qquad (2.7)$$

where S is the waterplane area, m^2;

H is the height of the freeboard, m.

The reserve buoyancy of surface ships of various types amounts to 100% or more of the displacement.

The residual reserve buoyancy of a damaged ship in m^3 is

$$A \quad \cdot A_0 - W - \Sigma v_{H1} - \Sigma v_{H2}, \qquad (2.8)$$

where A_0 is the reserve buoyancy of the undamaged ship at the time /26

of receiving damage, m^3;

W is the volume of water which has entered the compartments, m^3;

v_{H1} are the volumes of above-water compartments open to seawater, m^3;

v_{H2} are the volumes of above-water compartments with unsealed holes above the water.

4. Classification of Displacements

In a state of equilibrium, the mass M of a ship which is equal to the mass of the water displaced by the ship is called the mass displacement, or simply displacement, and is measured in tons.

Displacement is defined in terms of ship's burden. For warships the following classification of displacements (standard loads) has been established.

Light displacement is a displacement of a ship which is fully outfitted and ready for service. However, she has no crew and carries no ammunition, supplies, provisions, fuel, lubricants, and feed, fresh and drinking water in her tanks and machinery.

Standard displacement is a displacement of a ship completely ready for service, fully manned and ready to go to sea. She is loaded according to specifications with the exception of fuel, feed water and oil in the tanks and carries fuel, water and oil in systems, machinery, hot wells, and bilge tanks, i.e., her mechanical systems are completely ready to get underway.

Normal displacement (displacement at the official trial time) is a displacement equal to the standard displacement plus the supplies of fuel, lubricants, and feed water in the amounts of 50% of those specified for the full displacement of the ship.

Total displacement is a displacement equal to the standard displacement plus fuel supplies, lubricants and feed water in the amounts that guarantee the prescribed endurance at full or endurance speeds.

Maximum displacement is a displacement equal to the standard displacement plus ammunition which the ship can accommodate in the outfitted magazines or on the mine tracks on deck (in addition to the normal /27
supply specified for the standard displacement), as well as supplies of fuel, lubricants and feed water in the amounts sufficient to completely flood all the spaces intended for their storage.

For seagoing transport vessels displacement is classified as follows.

Light displacement is a displacement of a vessel ready to go to sea with all the shipboard equipment except for the cargo which the vessel is designed to carry, the crew, fuel, and all the consumables.

Loaded displacement is a displacement of a vessel with the maximum allowable draft and minimum allowable freeboard, as specified by regulations issued by classification organizations and by the Shipping Register in the USSR.

The difference between loaded and light displacements is the total load carrying capacity of a vessel, or its deadweight M_D. The weight of all cargoes and passengers with baggage constitutes the useful (or net) cargo carrying capacity of the vessel.

In addition, transport vessels are characterized by tonnage which is measures in m^3 or in register tons (1 register ton is equal to 2.83 m^3). Net register tonnage V_N is the volume of all spaces intended for carrying cargoes and passengers. Gross tonnage, or gross register tonnage V_G, is the volume of all the vessel's spaces.

An approximate relationship between register tonnage, deadweight, and loaded displacement is:

$$V_N = 2/3\ V_G = 4/9\ M_D = 8/27\ M. \qquad (2.9)$$

5. Buoyancy Characteristics of Submarines

When a submarine is completely submerged she can be in the state of equilibrium for only one fixed value of the force of gravity (weight):

$$P_s = \gamma V_s \qquad (2.10)$$

where V_s is the watertight volume of the submarine, (i.e. submerged volume displacement), m^3.

The equilibrium without a trim is possible only for one fixed position of the center of gravity of the submarine: /28

$$x_g = x_c \qquad (2.11)$$

where x_g is the abscissa of the center of gravity of force P_s;
x_c is the abscissa of the center of buoyancy of volume V_s.

A submarine whose load satisfies conditions (2.10) and (2.11) is

said to be statically trimmed. When these conditions are not satisfied the error determines the residual buoyancy:

$$Q = \gamma V_s - P_s \tag{2.12}$$

and the surplus trim moment:

$$M_t = P_s x_g - \gamma V_s x_c. \tag{2.13}$$

When $Q > 0$ the submarine rises, when $Q < 0$ she dives. When $M_t < 0$, the submarine acquires a trim by the bow and for $M_t > 0$ she acquires a trim by the stern.

In practice $Q \neq 0$ and $M_t \neq 0$. For the normal operation of a submarine, however, these values must remain within certain small limits. In calculations these limits are assumed to be zero.

In the submerged condition the reserve buoyancy of a submarine is equal to zero. A rapid increase in the buoyancy of a submarine can be achieved (without disturbing her trim) by blowing the main ballast tanks (MBT). The total volume of these tanks is the potential reserve buoyancy of the submarine in the submerged condition. Trimming is the altering of the submarine loading by means of the variable ballast in order to reduce the residual buoyancy and excess trim moment to zero. Ballast trimming is based on calculations and is checked during submergence trials of the submarine. Calculations of the ballast trim consists both in comparison of the total actual weight of the submarine and trim moments of variable loads (including the auxiliary ballast) with the similar total weight either under normal loads or under those existing during the preceding submarine trimming, and in compensation for any differences in total weights with the aid of the variable ballast. If necessary, an additional correction is made by taking into account the specific gravity of the seawater.

The basic submarine conditions are:

- full buoyancy condition; it is a surface condition of a trimmed submarine wherein all MBT's are blown, the negative tank is flooded, and the submarine is ready for crash diving; /29

- diving trim condition; it is a surface condition of a trimmed submarine wherein the midship group of MBT's are completely blown, the MBT's of the end groups are completely or partially flooded, the negative tank is blown, the stern diving planes are positioned at 15° for rising, the bow diving planes are rigged in, and the crew are at battle stations according to the condition of readiness No. 1, calling for sumberged operation. The submarine is ready for crash diving; and

- submerged condition; it is a condition of a trimmed submarine in which all the MBT's are flooded, the negative buoyancy tank is completely blown, the submarine is controlled by means of planes and can operate at depths ranging from periscope to maximum operating depth.

The reserve buoyancy of a submarine in the full buoyancy condition is equal to the total volume of the MBT's:

$$W = V \tag{2.14}$$

and the centers of buoyancy of these volumes lie on the same vertical:

$$x_W = x_V \tag{2.15}$$

where W and x_W is the reserve buoyancy in the full buoyancy condition and the abscissa of its center of buoyancy, respectively, in m^3 and m;

V and x_V is the total volume of the MBT's and the abscissa of its center of buoyancy in m^3 and m.

The use of MBT's without flood valves on a submarine decreases the reserve buoyancy because of the compression of the air cushions when the draft of the submarine increases and because of the forcing of air out of the air cushions during pitching and rolling in a seaway and during listing. A decrease in reserve buoyancy in a seaway can be as high as 30% of its value in calm water and large trims can result in the complete loss of reserve buoyancy.

Section 2.2. Stability

Stability is the ability of a ship to return to a state of equilibrium following the removal of the external forces which disturbed the equilibrium.

Static stability is observed when the forces causing a ship to incline act statically, without giving rise to angular velocity during /30
inclinations due to shifting of solid loads or transfer of fuel or water.

Dynamic stability is observed when the forces causing a ship to incline act dynamically, giving rise to significant angular velocities (e.g., the effect on a ship of blast waves, squall winds or water entering through holes).

1. Initial Stability

Initial stability is stability within small angles of inclination.

The metacentric formulas for initial stability are:

$$m_\theta = Ph\theta$$
$$M_\psi = PH\psi \qquad (2.16)$$

where m_θ is the righting moment for inclinations in the transverse plane (for a stable ship it acts in the direction opposite to that of the heeling moment);

M_ψ is the righting moment for inclinations in the longitudinal plane;

P is the force of gravity;

h is the transverse metacentric height, m;

H is the longitudinal metacentric height, m;

θ is the angle of heel, radians;

ψ is the trim angle, radians.

The moment (m_0) heeling the ship 1° is:

$$m_0 = Ph \sin 1^\circ = 0.0175Ph. \qquad (2.17)$$

The heel θ, in degrees, for a known heeling moment m_k is:

$$\theta = \frac{m_k}{m_0}. \qquad (2.18)$$

The moment trimming the ship by 1 cm (M_0) is:

$$M_0 = PH\frac{\Delta}{L} = 0.01\frac{PH}{L}, \qquad (2.19)$$

where L is the length of the ship, m.

The trim of a ship for a known trim moment M_t, in cm, is: /31

$$\Delta = \frac{M_t}{M_0} \qquad (2.20)$$

To insure the equilibrium stability the metacenter of the ship must

lie above the center of gravity, i.e., the metacentric height must be positive. In this case, for small inclinations there are righting moments which act in the opposite direction and which tend to return the ship to her original state of equilibrium (Fig. 2.2)

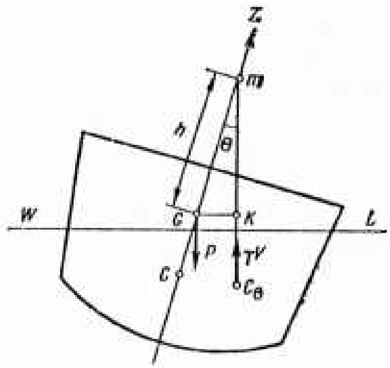


Fig. 2.2. Ship showing positive stability

The longitudinal metacenter is always located above the transverse metacenter so that a ship which is stable in the transverse plane is obviously also stable in the longitudinal plane. Therefore, a ship is considered to be stable if her transverse metacentric height is positive.

The initial stability of a ship is measured by the following:

1) coefficients of stability, i.e., values of the righting moment per unit angle of inclination. They make it possible to evaluate /32
directly the resistance which a ship exerts against forces deviating her from a state of equilibrium. The coefficient of transverse stability k corresponds to an inclination in the transverse plane while the coefficient of longitudinal stability K corresponds to an inclination in the longitudinal plane:

$$\left.\begin{aligned} k &= \frac{m_\theta}{\theta} = Ph; \\ K &= \frac{M_\psi}{\psi} = PH; \end{aligned}\right\} \qquad (2.21)$$

2) metacentric heights, i.e., coefficients of stability per unit weight of ship, in meters:

$$\frac{k}{P} = h; \ \frac{K}{P} = H. \qquad (2.22)$$

The metacentric height gives a relative estimate of the ship initial stability. One may conveniently use it in comparing various ships

from the standpoint of initial stability. The coefficient of stability must be used to evaluate the initial stability of a ship in the sense of her capacity to resist deviations from a state of equilibrium. Metacentric heights are calculated during the design of the ship; they are entered in the ship's book and updated according to the experimental data obtained during ship's operation. The optimum value of the transverse metacentric height h for cruisers is 0.9 to 1.3 m; for destroyers, 0.75 to 0.9 m; patrol boats, 0.6 to 0.8 m; seagoing minesweepers, 0.6 to 0.8 m; and torpedo boats, 1.0 to 1.5 m.

The transverse metacentric height h is related to the roll period of the ship in calm water by the following expression:

$$h\tau^2 = A, \tag{2.23}$$

where $A \approx$ constant.

If the period τ and the initial metacentric height h_0 are known from the preceding heel, then the initial metacentric height h, in meters, at a given time will be

$$h = h_0\left(\frac{\tau_0}{\tau}\right)^2, \tag{2.24}$$

where τ is the period of free oscillations, determined experimentally at a given moment, in sec. /33

2. Changes in Trim and Stability as a Function of Load Displacement

Let a load with weight p be shifted so that its center of gravity moves from point g_1 (x_1, y_1, z_1) to point g_2 (x_2, y_2, z_2). The position of the ship will not change because of the vertical shifting of the load. The transverse metacentric height h_1, however, will change. It will become equal to

$$h_1 = h + \delta h \tag{2.25}$$

where

$$\delta h = -\frac{p(z_2 - z_1)}{P}.$$

When the load is shifted upward $(z_2 > z_1)$ the transverse stability of the ship is reduced and when the load is shifted downward $(z_2 < z_1)$ the transverse stability is increased. The change in the longitudinal metacentric height will be negligible and, in practice, can be disregarded.

From the longitudinal and horizontal displacement of the load, the ship will acquire the following trim, in degrees:

$$\psi_1 = \frac{57{,}3p\,(x_2 - x_1)}{PH}. \tag{2.26}$$

As a result, her draft by the bow and stern will become:

$$\left.\begin{aligned} \delta T_H &= \left(\frac{L}{2} - x_F\right)\psi_1; \\ \delta T_K &= -\left(\frac{L}{2} + x_F\right)\psi_1. \end{aligned}\right\} \tag{2.27}$$

where L is the length of the ship, m;

x_F is the abscissa of the center of floatation, m.

From the transverse and horizontal displacement of the load the ship will acquire a heel θ, in degrees. In calculating the heel one must also bear in mind the change in stability owing to the vertical displacement of the load with weight p: /34

$$\theta = \frac{57{,}3p\,(y_2 - y_1)}{Ph_1}. \tag{2.28}$$

The transverse stability for a given displacement of the ship can be changed only by changing the moment of stability of her weight; in other words, by shifting the loads on the ship along the vertical.

3. Changes in Trim and Stability When Taking On and Using Up of Small Loads (Weight no greater than 10-15% of P)

Taking on a load changes the ship's trim (T, ψ, and θ) and stability. For small changes in ψ and θ the stability increases when the load received is placed below the neutral plane and decreases when it is placed above this plane. The plane of the initial waterline of the ship can be taken approximately as the neutral plane.

Let a load with weight p whose center of gravity is at a point whose coordinates are x, y, and z be taken aboard ship.

The ship's longitudinal stability remains practically unchanged from the acquisition of small loads.

The new trim and stability parameters will be:

- change in mean draft, m:

$$\delta T = \frac{p}{\gamma S}, \tag{2.29}$$

where γ is the specific gravity of water; and

S is the effective waterplane area, m^2;

- transverse metacentric height, m:

$$h_1 = h + \frac{p}{P+p}\left(T + \frac{\delta T}{2} - h - z\right); \qquad (2.30)$$

- angle of heel, in degrees:

$$\theta_1 = \frac{py}{(P+p)\,h_1}\cdot 57.3; \qquad (2.31)$$

- angle of trim, in degrees:

$$\psi_1 = \frac{p(x - x_F)}{(P+p)\,H_1}\cdot 57.3; \qquad (2.32)$$ /35

- forward draft T_{H1} and after draft T_{K1}:

$$T_{H1} = T_H + \delta T + \left(\frac{L}{2} - x_F\right)\psi_1; \qquad (2.33)$$

$$T_{K1} = T_K + \delta T - \left(\frac{L}{2} + x_F\right)\psi_1; \qquad (2.34)$$

- trim, m:

$$\Delta_1 = T_{H1} - T_{K1}; \text{ and} \qquad (2.35)$$

- mean draft, m:

$$T_1 = \frac{T_{H1} + T_{K1}}{2}. \qquad (2.36)$$

The same formulas should be used when loads are used up. However, in this case, one must take into account the fact that p is negative. In the event when several loads are received or removed simultaneously, these loads must be reduced to a single equivalent load.

4. The Effect of Liquid Cargoes on Stability

A liquid cargo filling a tank completely is equivalent to a solid well-secured load. For free flowing cargoes with the free surface the

4. The Effect of Liquid Cargoes on Stability

A liquid cargo filling a tank completely is equivalent to a solid well-secured load. For free flowing cargoes with the free surface the metacentric heights of the ship have the following increments in meters:

$$\left.\begin{aligned} \delta h &= -\frac{i_x}{V}; \\ \delta H &= -\frac{i_y}{V}. \end{aligned}\right\} \qquad (2.37)$$

where i_x and i_y are the moments of inertia of the free surface area of the liquid about the axes passing through the center of gravity of this area, m^4; and

V is the volume of the liquid cargo, m^3.

5. Changes in the Initial Stability When a Ship Goes Aground /36

When a ship goes aground its stability decreases. If the ship touches the sea bottom amidships the new metacentric height becomes

$$h_1 \approx h - \delta T, \qquad (2.38)$$

where δT is the change in the mean draft, m.

If a ship, trimmed by the bow, touches the sea bottom with the bow, the new metacentric height is

$$h_1 \approx h - \frac{0.14 T_H}{T_{cp}} \delta\Delta, \qquad (2.39)$$

where $\delta\Delta$ is the change in trim, m.

The decrease in the transverse metacentric height becomes greater with an increase in the trim by the bow, i.e. with an increase both in the ratio T_H/T_{cp} and the change $\delta\Delta$ of the trim of the ship as a result of her going aground. Going aground can be disastrous for a damaged ship with a large trim.

6. Static and Dynamic Stability Curves for Large Inclination Angles

A graph of static stability (stability curve) is a curve depicting the relationship between the righting moment or the stability arm and the angle of heel. The stability curve is computed for each ship by taking into account her displacement and the ordinate of the center of

gravity. Fig. 2.3 shows a typical stability curve for a ship with positive initial stability.

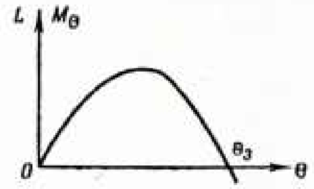


Fig. 2.3. Static stability curve

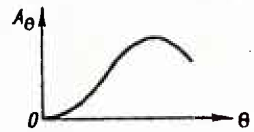


Fig. 2.4. Dynamic stability curve

The angle of heel θ_3 at which the stability curve intersects the horizontal axis, i.e., when the righting moment becomes zero, is called the angle of vanishing stability. For seagoing vessels the angle of vanishing stability is between 60 and 90°. As a rule, ships with high freeboards have large vanishing stability angles.

The static stability curve makes it possible to solve problems dealing with the determination of the heel of a ship as a function of the /37
static or dynamic effect of the heeling moment or, conversely, problems dealing with the determination of the heeling moment causing the ship to incline at a specific angle, i.e. to acquire the static or dynamic heel.

The dynamic stability curve (Fig. 2.4) is a curve showing the work performed by the righting moment as a function of the angle of heel. The work of the righting moment for the given inclination of the ship from the upright position to a given angle of heel, is

$$T_\theta = \int_0^{\theta_{dyn}} m_\theta \, d\theta. \qquad (2.40)$$

The dynamic angle of heel is the maximum angle which the ship acquires under the dynamic effect of the heeling moment. With a sudden application of a constant heeling moment, the dynamic angle of heel is about twice as large as the static angle of heel within the linear part of the static stability curve.

With the aid of the dynamic stability curve one can determine the following:

1. the dynamic heel for the case of a sudden application of a constant heeling couple to the ship; and

2. the greatest dynamic moment a ship can handle without capsizing.

7. Measures to be Taken for Maintaining Initial Stability of Ships

The initial stability of a ship can deteriorate because of the following:

- transfer of cargoes from lower to higher spaces;

- taking on cargoes in spaces located above the waterline; /38

- using up cargoes located in spaces lying below the waterline;

- presence of liquid cargoes with a free surface;

- presence of unsecured cargoes;

- touching the supports of a dock;

- touching sea bottom;

- reducing the effective waterplane area as a result of large trims.

When a ship is heeling the righting moment is reduced by the magnitude of the heeling moment. The longitudinal stability is reduced substantially when either end of the deck enters the water.

External indications of the low initial stability:

- inclination of the ship (upon application of heeling moments) through large angles which do not correspond to the values given in the tables;

- extremely smooth rolling;

- inclination of the ship when turning, with the angles greatly exceeding the theoretical turning angles.

Measures preventing stability deterioration below the prescribed level:

- strict observance of instructions for receiving and using up fuel; these instructions provide for the optimal--from the standpoint of maintaining ship stability--distribution of fuel in tanks at all times;

- systematic accounting for the presence and distribution of variable cargoes, especially liquid cargoes, as well as measurement of the draft and determination of the ship's water displacement;

- systematic monitoring and maintaining stability within the prescribed limits;

- taking measures to improve stability when receiving additional cargo and when the ship is icing up.

To maintain stability within the prescribed limits it is necessary:

- to use up and take on liquid cargoes so as not to allow the formation of large free surfaces;

- to place all variable cargoes in areas provided by the ship's design; cargoes which can move must be safely secured; /39

- not to allow the flow of liquid cargoes from the tanks on one side into the tanks on the other side of the ship;

- not to allow the accumulation of water in holds, on decks and especially in large spaces located above the effective waterline;

- to drain the water immediately after the sealing of holes in damaged compartments by means of the water removing equipment;

- to chop the ice and dump it overboard whenever the deck, masting and rigging freeze over;

- to determine immediately the reason for the onset of the heel or trim and to eliminate them as quickly as possible;

- to regulate strictly the weight distribution aboard ship.

8. Stability Characteristics of Submarines

In the submerged condition the submarine does not exhibit form stability. All her metacenters coincide with the center of buoyancy which, in order to insure stability, must be located above the center of gravity of the submarine.

The condition for stability is

$$z_c > z_g, \tag{2.41}$$

where z_c and z_g are the z-coordinates of the center of buoyancy and center of gravity of the submarine in the submerged condition, m.

The transverse and longitudinal metacentric heights are equal to one another:

$$h = H = z_c - z_g. \tag{2.42}$$

The transverse and longitudinal stability arms are:

$$\left.\begin{aligned} l_\theta &= h \cdot \sin\theta; \\ l_\psi &= H \cdot \sin\psi. \end{aligned}\right\} \qquad (2.43)$$

The angles of the static stability curve maximum are equal to 90°, while the angles of vanishing stability are equal to 180°.

The transverse metacentric height, obtained by taking into account the overflowing of the liquid cargoes, is:

$$h = z - z_g. \qquad (2.44)$$

The correction for the overflowing is

$$\delta h = z - z_m. \qquad (2.45)$$

The metacentric height without the correction is /40

$$h_0 = z_m - z_g, \qquad (2.46)$$

where $z = z_m + \delta h$; and

z_m and z_g are the ordinates of the curves $z(T)$, $z_m(T)$ and $z_g(T)$ for the given draft T, in meters.

Whenever the top stringers of the MBT's and pressure hull become submerged, the initial stability of the submarine falls sharply because of the decrease in form stability. The corresponding area on the graph (Fig. 2.5) is called the "neck."

In the full buoyancy condition the metacentric heights of a submarine are:

- transverse, h = 0.2 to 0.6 m;

- longitudinal, H = (0.8 to 1.5) L, where L is the length of the submarine, m.

In the submerged condition h = H = 0.2 to 0.6 m.

During diving the positions of the center of buoyancy C, transverse metacenter m, and of the center of gravity g in a submarine change. This is shown graphically in Fig. 2.5.

Before submergence of the pressure hull the center of buoyancy /41

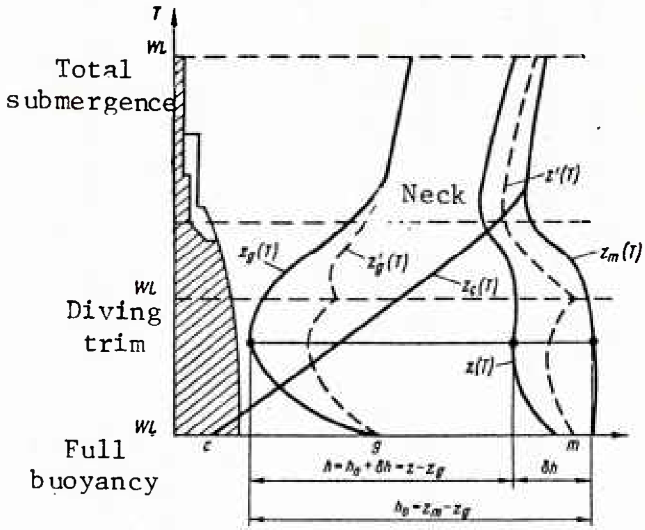


Fig. 2.5. Graph of the initial stability of a submarine during diving and surfacing.

moves upward rapidly and then more slowly. With the total submargence of the submarine the position of the center of buoyancy does not change. When the submarine rises the center of buoyancy moves in the opposite direction.

During submergence the transverse metacenter moves down and with the total submergence of the pressure hull, the transverse metacenter coincides with the center of buoyancy. During rising of a submarine the transverse metacenter moves in the opposite direction.

With the flooding of the lower parts of the MBT's the center of gravity moves down somewhat, and with the flooding of the middle and upper parts it moves up. When the main ballast tanks are completely flooded, the center of gravity is located higher than in the full buoyancy condition. When the submarine rises the center of gravity moves in the opposite direction.

In Fig. 2.5 the solid curves correspond to the case of diving (or surfacing) accomplished by a submarine in one step, and the dashed curves correspond to the case of diving or surfacing made in two steps. Using this graph one can analyze the change in the transverse metacentric height h during submergence or surfacing made in one or two steps.

Section 2.3. Controllability

Controllability is the ability of a ship to maintain a given heading and, if necessary, to change it by means of the rudder or by some other means. The ability of a ship to maintain a given heading is called directional stability and the ability to change the heading is called maneuverability.

1. Maneuverability of a Ship

The maneuverability of a ship is characterized by the time required to change course and by the turning circle, i.e., by the path of the ship's center of gravity when the ship is turning. The three characteristic periods in a turning circle are:

- the maneuvering period, i.e. the period from the beginning to the end of the rudder angle application; due to the increase in the rudder angle the force acting on the rudder gradually increases;

- the evolution period, i.e. the period between the time the rudder angle application ends and the beginning of steady motion; it ends approximately at the time when the ship changes her direction by 90 to 120° relative to the original course; /42

- the period of steady turning is the period during which the center of gravity of the ship moves along a circular path with an almost constant velocity.

When a ship turns in a circle she acquires a certain heel and trim. The trim is usually very small and the heel can become considerable. During the maneuvering period the ship heels in the direction of the rudder, i.e., toward the center of the turning circle. During the period of steady turning the ship heels in the direction away from the center of the turning circle.

The basic parameters of the turning circle are (Fig. 2.6):

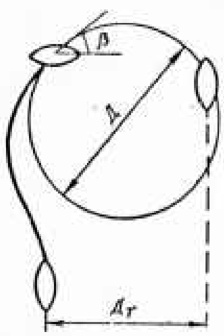


Fig. 2.6. Basic parameters of the turning circle

- turning diameter D, which is the diameter of the circle described by the center of gravity of the ship during the period of steady motion; the ratio D/L is called the relative diameter of the turning circle or the measure of maneuverability of the ship; the magnitude of D/L is between 4 and 7;

- tactical diameter D_T of the turning circle is the perpendicular distance from the original course to the position where a ship has turned through an angle of 180°.

- period of the full turn is the interval of time in the course of which the ship completes a 360° turn;

- angle of drift β is the angle between the tangent to the path of the ship's center of gravity and her center line.

The maximum heel, in degrees, of the ship during steady turning is:

$$\theta_{max} = 1.4 \frac{v_0^2}{hL} \left(z_g - \frac{T}{2} \right). \qquad (2.47)$$

where v_0 is the speed of the ship on the forward course before turning, m/sec; /43

H is the transverse metacentric height, m;

L is the length of the ship, m;

z_g is the ordinate of the ship's center of gravity, m;

T is the mean draft of the ship, m.

The factors which affect controllability and which depend on the ship are the speed, heel, trim, and the design of the ship. The external factors affecting controllability are the direction and force of the wind, the presence of seaway and its direction, the nature of the depths, and the velocity and direction of currents.

2. The Action of the Rudder

With the ship underway the following forces act on the rudder to which a rudder angle was applied:

- the force of the head sea acting both with headway and sternway; it ceases to act when the ship stops;

- the screw current force reaching a maximum value on the rudder blade placed astern of the propeller; this force may act throughout the

entire period of the ship's headway and for ships with rudders mounted abaft the propeller it prevails over all other forces;

- the force due to discharge of the mass of water on the other side of the rudder plane; it tends to return the rudder amidships.

When moving ahead with the rudder shifted through a certain angle from the center plane, a hydrodynamic force A begins to act on the rudder. Its components (Fig. 2.7) are:

- A_x is the rudder drag force which reduces the speed of the ship;
- A_y is the turning force which causes the stern of the ship to swing in the direction opposite to that of the rudder.

When the ship is backing the A_y component swings the stern in the direction of the rudder and A_x causes the speed to decrease. Thus, with sternway, the bow of the ship turns in the direction opposite to that of the rudder (Fig. 2.8).

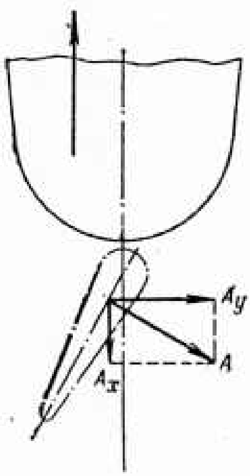


Fig. 2.7. Forces acting on the rudder during headway

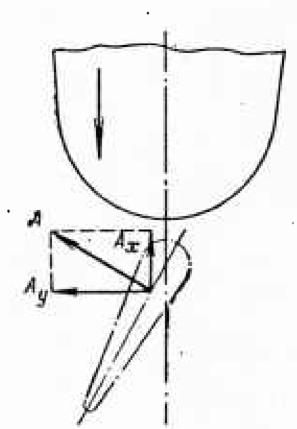


Fig. 2.8. Forces acting on the rudder during backing

In all instances the greater the speed of the ship and rudder angle the more rapidly will the ship turn. However, at large rudder angles the rudder drag increases sharply and, consequently, the speed of the ship decreases. Therefore a rudder angle greater than 25-30° is not recommended. /44

3. Controllability of a Submarine in the Submerged Condition

The movement of a submarine in the submerged condition is characterized by:

- motion in the horizontal plane or change in course at a constant depth;

- motion in the vertical plane or change in depth on a constant course;

- three-dimensional motion or maneuvering with the simultaneous change in depth and course.

The maneuverability of a submarine in the horizontal plane varies within D = (3.5 to 8.0) L. The heel, during all periods of turning, is inward, i.e., the heel occurring during the maneuvering period increases throughout the evolution period, reaches its greatest value during steady turning, and remains constant until the end of the turn. /45

The controllability in the vertical plane is the ability of a submarine to maintain the given heading in the vertical plane as well as to change it by means of the diving planes and propellers. The controllability of a submarine in the vertical plane involves two characteristics--stability of motion and maneuverability in the vertical plane. The diving planes are the basic components insuring the controllability of a submarine in the vertical plane. Controllability depends on the speed and trim of the submarine.

The following parameters characterize the motion of a submarine in the vertical plane (Fig. 2.9):

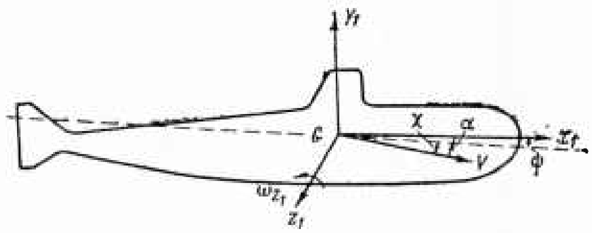


Fig. 2.9. Parameters of motion of a submarine in the vertical plane

- speed ahead V of the submarine;

- angle of attack α is the angle between the veolcity vector and longitudinal axis x_1 of the submarine;

- angle of trim ψ is the angle between the level line and longitudinal axis x_1 of the submarine;

- path angle α is the angle between the level line and the velocity vector;

- angular velocity ω of the submarine about the transverse axis z_1.

The following forces and moments act on a submarine during her motion in the vertical plane (Fig. 2.10):

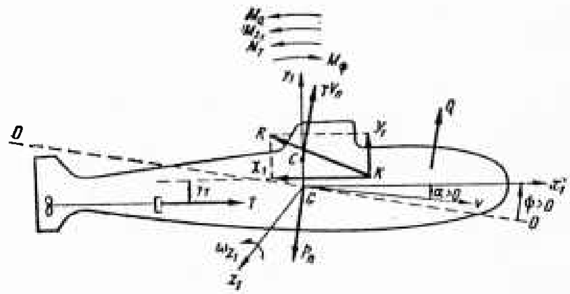


Fig. 2.10. Forces and moments acting on a submarine during motion in the vertical plane

- static forces and moments;

- hydrodynamic forces and moments; and

- force and thrust moment of the propellers.

Static forces and moments include the force of gravity P_π (weight) /46 and the buoyancy force γV_π. These forces produce the righting moment $M\psi = \gamma V_\pi h_\pi \mathrm{Sin}\psi$. The residual buoyancy force is $Q = \gamma V_\pi - P_\pi$ and the moment is M_Q.

Hydrodynamic forces and moments include forces produced by the effect of water on the hull of a submarine during her movement. The resultant R of these forces is called the main hydrodynamic force vector. The point of application of the main vector is the pressure center K. The component R parallel to the x_1 axis is the longitudinal hydrodynamic force X_1; the component parallel to the y_1 axis is the normal hydrodynamic force Y_1. When $\alpha > 0$, y_1 is positive, i.e., a lift force is exerted on the hull of the submarine; when $\alpha < 0$ a downward force acts on the hull of the submarine.

The moment of the thrust force of the propellers is

$$M_T = T \cdot y_T \qquad (2.48)$$

where T is the thrust force of the propellers and

y_T is the vertical distance between the center of the thrust bearing and the center of pressure of the submarine, m.

If all forces and moments acting on a moving submarine are in a state of equilibrium and the motion itself is characterized by constant parameters, then, dynamically, the submarine is in equilibrium. The dynamic equilibrium is achieved by a submarine only through the proper shifting of diving planes or adjusting the trim. /47

If the diving planes of a submarine moving with speed V are deflected at a certain angle α, hydrodynamic forces will begin acting on the planes, the resultant R of which acts at the center of pressure of the planes (Fig. 2.11).

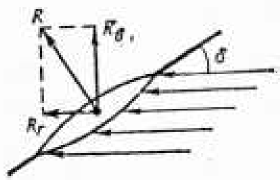


Fig. 2.11. Effect of the diving plane making an angle with the oncoming stream

The resultant R can be resolved into two components: horizontal component $R_Г$ and vertical component R_B. The former component ($R_Г$) will slow down the submarine while the latter component (R_B) together with its moment M_B about the center of gravity of the submarine will change the direction of the submarine motion in the vertical plane.

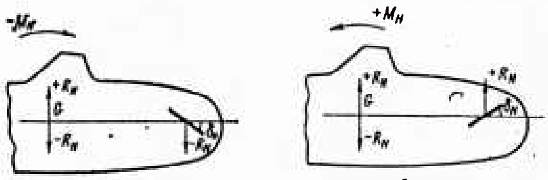
If the diving planes create a trim by the bow then a minus (-) sign is assigned to the trim and one speaks of the planes as being rigged for diving. If the diving planes create a trim by the stern then a plus (+) sign is assigned to the trim and one speaks of the planes as being rigged for rising. If the vertical component R_B tends to rise the submarine it is considered to be positive ($+R_B$) and if it tends to lower her, it is considered to be negative ($-R_B$).

Using the diving planes separately:

- the bow planes are rigged for diving (or rising); in such a case a vertical force which is directed downward ($-R_H$) or upward ($+R_H$) is

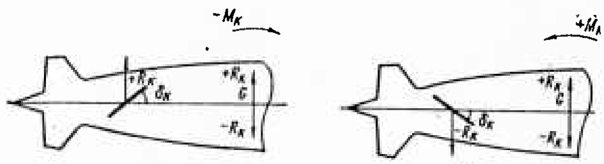
produced together with a trim moment ($-M_H$) by the bow or by the stern ($+M_H$). Under the effect of the vertical force ($-R_H$) or ($+R_H$) and trim moment ($-M_H$) or ($+M_H$) the submarine will dive (or rise) (Fig. 2.12);

- the stern planes are rigged for diving (or rising); in such a case a vertical force which is directed upward ($+R_K$) or downward ($-R_K$) is produced together with trim moments by the bow ($-M_K$) or by the stern ($+M_K$). Under the effect of force ($+R_K$) or ($-R_K$) and trim moment ($-M_K$) or ($+M_K$) the submarine will dive (or rise) (Fig. 2.13). /48



a b

Fig. 2.12. Bow planes are rigged
a - for diving; b - for rising



a b

Fig. 2.13. Stern planes are rigged
a - for diving; b - for rising

Using the diving planes together:

- the bow and stern planes are rigged in the opposite directions for diving (Fig. 2.14 a); in such a case forces $+R_H$ and $+R_K$ are produced together with the trim moment $-M_H$ by the bow and the trim moment $-M_K$ by the stern; the submarine will dive;

- the bow and stern planes are rigged in the opposite directions for rising (Fig. 2.14 b); in such a case, forces $+R_H$ and $-R_K$ are produced together with the moments trimming the submarine by the stern; the submarine will rise;

- the bow planes are rigged for rising and the stern planes are rigged for diving (parallel position is for rising, Fig. 2.14 c); in such a case forces $+R_H$ and $+R_K$ are produced; the bow planes will create a trim moment $+M_H$ by the stern while the stern planes will produce a trim moment M_K by the bow; when the trim moments become equal the submarine begins to rise; /50

- the bow planes are rigged for diving and the stern planes are deflected for rising (parallel position is for diving, Fig. 2.14 d); in such a case forces R_H and $-R_K$ are produced; the bow planes create a trim moment $-M_H$ by the bow, and the stern planes produce a trim moment $+M_K$ by the stern; when the trim moments are equal the submarine dives.

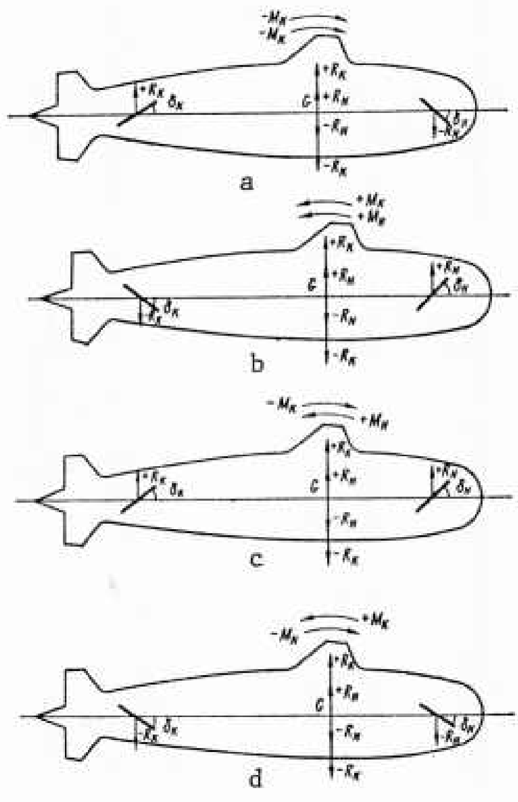


Fig. 2.14. Using diving planes together:

a - planes rigged in the opposite directions for diving;
b - planes rigged in the opposite directions for rising;
c - planes are in parallel for rising;
d - planes are in parallel for diving.

Deflecting the planes in the opposite directions is used along with trimming for rapid changing of the operating depth. As a rule, the parallel deflection of the planes--with almost no trimming--is used for making small changes in the operating depth of the submarine. The motion of the submarine in the vertical plane can be either steady--with constant speed, angles of attack, and trim; or unsteady, in which case one or several parameters (speed, angle of attack or trim) change in time.

The angles of attack and the plane angles at which the forces and moments acting on the submarine are balanced and, as a result of which the submarine performs steady horizontal motion, are called trimming angles. Trimming can be accomplished by either of the planes used simultaneously or separately.

A loss in controllability of a submarine can occur when, at low speeds, she is controlled by means of the stern planes. The speed at which a loss in controllability occurs is called the inversion speed. Its magnitude lies within 1.5 to 3.5 knots.

Section 2.4. Concept of the Speed-to-Power Ratio of Ships with New Propulsion Principles

The speed/power ratio is the ability of a ship to develop a given speed with minimum consumption of power.

In order to increase the speed/power ratio of ships, the following new propulsion principles have been introduced in shipbuilding: planing by means of hydrofoils; creating a layer of compressed air--static air cushion; or using the velocity head of an oncoming stream of air when flying near the surface of the water. /51

1. Planing Ships

When planing, a ship is maintained on the water surface by hydrodynamic lift forces.

The speed of a vessel for which planing is possible is, in m/sec^2:

$$U_{\text{глисс}} = 3\sqrt{g\sqrt[3]{V}}, \tag{2.49}$$

where g is the acceleration due to gravity, m/sec^2; and

V is the displacement of the vessel, m^3.

The application of the planing principle of propulsion required special shapes for vessels such as plane or almost plane load carrying surfaces. The degree of perfection of the shape of the vessel is

characterized by the lift-drag ratio K:

$$K = \frac{\gamma V}{W}, \tag{2.50}$$

where γ is the specific gravity of water, (ton-force)/m^3;

V is the volume displacement of the vessel, m^3; and

W is the resistance to motion.

The transition to the planing mode is characterized by a marked reduction in water resistance, a fact which makes it possible to achieve very high speeds. However, this is possible only in still water since planing craft do not exhibit a high degree of seaworthiness.

2. Hydrofoil Ships (Craft)

The use of hydrofoils for moving in water is based on the property of the foil to create a lift force when a stream of liquid moves past the foil. When a ship moves at a high speed the hydrodynamic lift force of the hydrofoil is sufficient to overcome the weight of the ship and to raise her hull out of the water. This results in a significant /52
reduction in resistance to the ship's motion and, consequently, in an increase in speed. For the same propulsion power the speed of boats and ships using hydrofoils increases two to three times in comparison with the conventional displacement vessels.

For stable operation at any steady speed in the foilborne mode, the lift force of the hydrofoil ship must equal her weight.

Hydrofoil systems are divided into three basic types according to the method used in controlling the lift force (Fig. 2.15):

1) surface-piercing hydrofoils (Fig. 2.15 a, b, c);

2) flat, slightly submerged hydrofoils (Fig. 2.15 d); and

3) deeply submerged, automatically controlled hydrofoils (Fig. 2.15 e).

The deeply submerged, automatically controlled hydrofoils providing a high degree of seaworthiness are usually used on seagoing hydrofoil ships.

The lift-drag ratio of the hydrofoil is:

$$K = \frac{Y}{X} = \frac{C_y}{C_x} \tag{2.51}$$

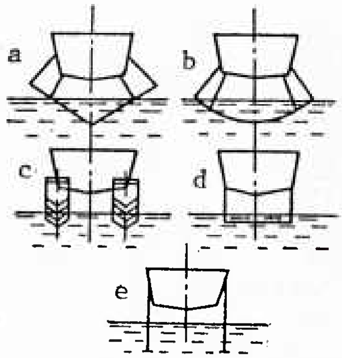


Fig. 2.15. Basic types of hydrofoil systems:

a, b, c - surface piercing hydrofoils;
d - flat, slightly submerged hydrofoils; and
e - deeply submerged, automatically controlled hydrofoils.

where C_y is the coefficient of the lift force of the hydrofoil; and
C_x is the coefficient of resistance to motion of the hydrofoil.

In the foilborne mode, when the hull of the ship is above water, the drag is: /53

$$R = R_K + R_B + R_A \tag{2.52}$$

where R_K is the drag of the hydrofoils, T(F);
R_B is the drag of appendages, T(F); and
R_A is the air drag, T(F).

3. Air Cushion Vehicles

The idea of the principle of motion on an air cushion involves the creation of a lift force by forming a region of increased pressure, i.e., a static air cushion under the ship's bottom. With the aid of this cushion the ship is maintained at a certain height above water or ground. Typical of ships using air cushions is the insignificant role (in the overall balance of resistance to motion of the craft) played by frictional and wave making resistances which are the basic components of the total drag in conventional displacement ships and vessels.

Air cushion vehicles are classified as follows:

Type I - air cushion vehicles which ride completely clear of the

surface of the water and which use closed flexible skirts; and

Type II - air cushion vehicles which use rigid side walls (skegs), with flexible skirts only forward and aft.

Type I air cushion vehicles are amphibious while those belonging to Type II are used only in water. Type I vehicles have substantially less resistance than Type II. Propulsion systems use, primarily, air screws. When moving at low speeds, Type I air cushion vehicles have an increased tendency to ship the heavy spray produced by the peripheral flow of air from the flexible skirt. Type II air cushion vehicles, which are always in contact with the water surface, can, in addition to air screws, use hydrojets and water propellers.

4. Surface-Effect Ships /54

Surface-effect ships are machines which use the velocity head of the oncoming air stream for the formation of a dynamic air cushion when flying close to a screening surface (such as water surface). The surface-effect ship moves at a relatively low height above the surface in her near-the-screen operating mode. Movement on air eliminates the effect of the water drag. This makes it possible for the surface-effect ships to develop speeds of up to 200 knots (according to data published abroad) with comparatively small consumption of power.

In addition to high speed, the advantages, according to the non-Soviet data, of surface-effect ships in comparison with air cushion vehicles and hydrofoils are:

- improved seaworthiness because there is no contact with water and because of the ability of these ships to change altitude depending on the sea state; and

- long operating range due to the high speed and aerodynamic lift-drag ratio of these craft.

One of the special features of surface-effect ships is their ability to operate in various modes, such as the navigating and planing modes and in their basic mode--moving above ground close to the screening surface.

Section 2.5. Maneuvering Properties

The maneuvering properties of a ship are the characteristics describing her movement. They include the speed of the ship at various propeller rpm; the reversing time; the time needed to develop the required speed from various positions (or conditions) of the engines; inertia;

and turning ability (see Section 2.3). For a submarine, in addition to the above, the maneuvering properties include the vertical maneuverability when submerged, which depends mainly on the submarine speed and the angle of the diving planes. The maneuvering properties are determined through a special program of shipyard performance trials and official acceptance trials following the construction of the ship. These properties are recorded in the ship's specifications book. They do not remain constant and therefore must be updated regularly. The maneuvering properties of a ship are recorded in tables which are kept at the control stations and in the navigation department of the ship.

The speed of a ship is the distance traveled per unit time; it is usually expressed in knots (nautical miles per hour). Speeds are /55
classified as follows:

- flank speed--the greatest speed a ship can develop by forcing the main and auxiliary engines under the condition of total combat readiness; ordinarily this speed is used under extreme circumstances by single ships and only for short periods of time;

- full speed--this speed is developed with the main propulsion engines operating at full power, normal displacement, and with all weapon systems and ship equipment operating properly in the mode insuring the total combat readiness of the ship;

- operational speed--this speed is developed with the minimum consumption of fuel (energy) per mile traveled, normal displacement, and with all weapon systems and ship equipment operating in the mode insuring the total combat readiness of the ship and the readiness of the main engines to develop full speed;

- endurance speed--this speed is developed with the minimum consumption of fuel (energy) per mile and with only those systems operating which are required to maintain the prescribed combat readiness of the ship and provide for the daily needs of personnel; and

- steerageway--the lowest speed at which the ship can be steered with the propulsion engines operating stably.

Submarine speeds are additionally classified as follows:

- low-noise speed--the speed at which the submarine moves while producing minimum amount of acoustic emission; and

- inversion speed--the speed at which the submarine loses control over the stern planes.

The ship's tactical characteristics, associated with her speed, include the following:

- endurance--the distance a ship travels at a given speed and uses up all her fuel supply (except for her reserved supply of fuel needed to prepare the power plant for operation and the minimum supply required by the ship to enter the base); and /56

- operational radius--the maximum distance from the base a ship can travel at operational speed and have enough fuel for engaging in a battle and for her return trip; under ordinary conditions the operational radius does not exceed, on the average, 40% of the total endurance of single ships steaming at operational speed.

The ship's inertia is the ability of a ship to maintain motion existing during the initial operational mode of the engines and following the change of that mode. The parameters of inertia such as the distance traveled by inertia and the duration of motion are determined experimentally for various speeds.

The officer of the watch must know exactly the following inertia parameters for his ship:

- the distance and time interval from the moment the engines are stopped until the ship comes to a complete halt; and

- the distance and time required to completely stop the ship after the engines are reversed from the full, medium or low speed ahead to the full speed astern.

Section 2.6. Effect of the Operation of the Screws on the Controllability of Ships

The screws have no lesser effect on controllability of a ship than does the rudder. Depending on the direction of their rotation with the ship moving ahead, one speaks of a right-handed screw rotating clockwise and a left-handed screw rotating counterclockwise, when looking from aft in the direction of motion.

When handling a single-screw ship the following is observed:

- at the moment the ship gets underway the stern of a single-screw ship turns in the direction of rotation of the screw. In order to keep the proper heading after giving the ship her forward speed, it is necessary to put the rudder over to starboard for a short interval of time when using the righthanded screw or to port when using the left-handed screw;

- due to the force of discharge a single-screw ship with a steady speed ahead responds well to the rudder. As a rule, to keep a ship on a straight heading the rudder must be deflected slightly in the direction

opposite to the rotation of the screw; /57

- a single-screw ship turns more readily, and with a smaller turning-circle diameter, in the direction of rotation of the screw;

- a single-screw ship responds to the rudder better when making headway than when making sternway. With a single-screw ship making sternway it is almost impossible to keep her on a straight heading even with the hard rudder;

- with a sternway the ability of a ship to turn to port or starboard varies. With a right-handed screw the ship's stern turns more readily to port than to starboard and with a left-handed screw, the opposite is true;

- in order to turn a ship in restricted waters the rudder must be deflected in the direction of the turn while periodically giving the engine full speed for short periods of time so as not to impart forward motion to the ship. In individual cases, especially with strong winds and currents, an anchor must be used in order to make the turn;

- a ship at anchor must be approached as follows: if the side of the ship being approached and the direction of rotation of own screw are the same, then one approaches at an angle of 20-30°; if the side of the ship being approached and the direction of rotation of own screw are different, then one approaches with a heading parallel to the side of the ship at anchor.

When handling a twin-screw ship the following is observed:

- twin-screw ships with a single rudder do not respond to the rudder as well as single-screw ships do since the force of discharge of their screws is considerably smaller; the turning-circle diameter for twin-screw ships is the same for both directions of turning;

- the speed of turning of a twin-screw ship with no way on, produced by using only her engines, is much lower than that obtained for a ship moving ahead, i.e., when the rudder facilitates the accomplishment of the turn;

- when using one engine and moving ahead the ship can be kept on course relatively easily by putting the rudder over to the side of the operating engine;

- when navigating in narrow channels where it may be necessary to quickly cancel the headway inertia while keeping the ship on course, both engines must be reversed simultaneously;

- with her engines stopped, the ship responds well to the rudder

when moving under a considerable inertia astern;

- with the steering gear out of order, a twin-screw ship can, even when her rudder is locked at a small angle of up to 5^{0}, maintain her proper sternway and perform maneuvering by controlling the rotational speed of her screws. /58

When turning a twin-screw ship by means of the engines, one operating ahead and the other astern, it is necessary:

- to give the engine operating ahead a speed one degree less than that of the engine operating astern when twisting the ship in her own water with no way on;

- to give both engines equal speed or to give the engine operating astern a speed one degree lower than that of the other engine when turning a ship moving ahead;

- to give the engine operating astern a speed of two, three, or four degrees higher than that of the engine operating ahead when turning a ship moving astern;

- to use the rudder along with the engines to increase the turning speed in all instances when a ship is turning while moving ahead or astern;

- to avoid using the rudder when twisting the ship in her own water with no way on. Since the ship is not moving ahead and there is no head sea, using the rudder in such a case would not facilitate the turn and in fact may prove to be a wrong thing to do.

When handling a triple-screw ship the following is observed:

- triple-screw ships exhibit better controllability than twin-screw and single-screw ships since they combine the favorable characteristics of both;

- triple-screw ships, just as twin-screw ships, are easily controlled with the aid of the engines when the steering gear goes out of order; in this case, one should move with the center screw rotating with a constant speed, while keeping the ship's heading and making turns by controlling the speed of rotation of the side screws;

- the diameter of the turning circle of triple-screw ships are minimal when using only the center engine; it is somewhat larger when operating with three engines, and it becomes maximal when only two side engines are used;

- when mooring aft one should go astern with the center engine and

operate the side engines so that the ship's center plane remains perpendicular to the mooring line.

When handling a ship with a variable-pitch propeller the following /59 is observed:

- the use of a variable-pitch propeller greatly improves the maneuverability of a ship because of the more gradual variation in the propeller thrust and, consequently, the ship's speed, and because of the reduction in the ship reversing and stopping time, i.e., the time required to develop a given speed;

- the speed of the ship can be changed by changing the speed or the pitch of the propeller without changing the direction of the propeller shaft rotation; the ship's direction (ahead, stop, astern) can be changed only by changing the propeller pitch. The position of the blades in the variable-pitch propeller is monitored by means of the remote pitch indicators;

- when maneuvering a ship to approach or leave a pier (or another ship) it is recommended to keep the screw speed constant within the limits prescribed by the appropriate instructions for each class of ships;

- in all instances, except for special cases, the load on the main engines must be changed gradually in the following manner: to increase the ship's speed one should first increase the propeller pitch and then its speed; to decrease the ship's speed one should first decrease the speed of the variable-pitch propeller and then its pitch.

Note: special cases include maneuvers executed to perform the following:

- to avoid collision with another vessel;

- to evade enemy attack;

- to leave an area contaminated with radioactive substances;

- to rescue a man overboard (in peacetime and outside the combat area).

In executing turns one should be guided by the following regulations:

- the Commanding Officer of the ship designates the course and speed of the ship through the watch officer;

- before beginning a turn, that is, before giving the command for the rudder, one should make sure that no other ships, boats or navi-

gational hazards are present in the area to which the turn is being made;

- only standard commands to the helmsman must be used; the helmsman must repeat them in a loud voice, preceding the repetition with "Aye, aye, Sir;"

- when executing turns in narrow channels and harbors, in addition to watching the ship's bow, it is necessary to watch the move- /60
ment of the stern as well since the stern swings much faster and can cross beyond the limits of the marked off area.

- put the rudder hard over only if necessary (for example, to make a turn in the narrow channel to avoid collision with another ship or running aground, when performing combat maneuvers, etc.);

- when the ship is moving with considerable speed and experiencing severe rolling, it is recommended (especially for small ships) to reduce the speed and not to deflect the rudder through large angles when turning; otherwise, the amplitude of the roll may coincide with the heeling moment produced by turning and endanger the ship by producing a situation in which the total angle of heel can exceed its critical value. When giving commands to the helm the watch officer must always be aware of the probable heel magnitude;

- always be prepared for a swift change to standby steering systems; all rudder control instruments and systems for communicating with them must be in a state of constant readiness.

In addition to the above, the following regulations must be observed when in the company of other ships:

- the turning ship must display a flag or light signal, from the moment the command is given to the helm until the end of the turn;

- when changing course in a column, turning must be made along the inner edge of the wake of the ship ahead;

- the rudder must always be set at an angle corresponding to the diameter of the turning circle specified for the formation.

CHAPTER 3

SHIP DAMAGE CONTROL

Section 3.1. Ensuring Ship Survivability /61

Survivability is the ability of a ship to remain afloat when one or several of her compartments are flooded, while maintaining and restoring (to the extent possible) her combat effectiveness and seaworthiness.

The survivability of a ship is insured by the following:

- design measures taken during the construction or modernization of the ship;

- organizational and technical measures taken throughout the entire life of the ship; and

- damage control measures taken whenever the ship sustains damage.

Ensuring the ship's survivability involves a set of actions to be taken by the crew of a damaged ship and directed toward:

- keeping the ship afloat;

- reducing the heel and trim to a degree which would enable the ship to get underway, restore her controllability and the ability to use weapons; and

- restoring the reserve buoyancy and stability to the extent which would prevent the ship from sinking or capsizing.

The action taken by the crew of a damaged ship must include three basic groups of measures:

1) Measures aimed at stopping the flow of water throughout the ship, restore and maintain the watertight integrity and strength of bulkheads and decks, and seal holes above the water.

Whenever water enters a damaged compartment the water removal equipment should be actuated at once. The crew then proceeds to seal off the compartment and repairs holes. Doors, hatches, and openings are battened down; damaged ship systems which run through the flooded area and which could serve as the path for spreading water throughout /62
the ship are disconnected. If necessary, the watertight bulkheads of adjacent spaces are reinforced.

2) Measures to determine the condition of the damaged ship in order to evaluate the danger she faces, to explore the feasibility of improving her condition and to develop damage control steps to be taken to ensure the survival of the ship.

In order to determine the condition of a damaged ship it is necessary:

- to determine the location of the damage and the nature of the flooding of compartments;

- to estimate the remaining reserve buoyancy of the ship;

- to estimate the change in stability as a result of the damage; in particular, to determine the probability of the ship's acquiring negative initial stability; and

- to determine the ship's status (heel, trim, and mean draft).

3) Measures to restore stability and to right the ship.

1. Determining the Trim and Stability of a Damaged Ship

In terms of the nature of flooding (Fig. 3.1.), ship compartments are classified as follows:

- Category I compartments are compartments (both communicating and not communicating with seawater) which are completely flooded and closed at the top. A characteristic feature of these compartments is the constant quantity of water (by weight and volume) that has entered them;

- Category II compartments are compartments which are not completely flooded and are not communicating with seawater. These compartments are characterized by a fixed quantity of water within, which, when the ship inclines, flows over to the inclined side and increases the heel, i.e., decreases ship's stability;

- Category III compartments are compartments which are not completely flooded but are communicating with seawater. A characteristic feature of these compartments is the dependence of the level of water within them on the trim of the ship. With a change in the ship's trim the quantity of water within them and the position of the center of gravity of the water change. /63

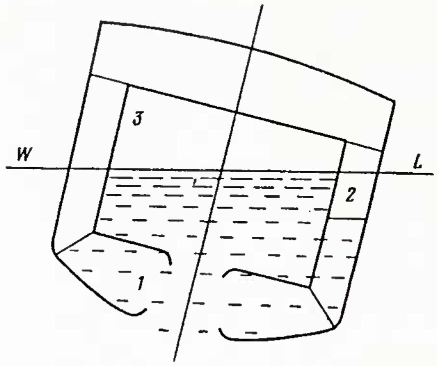


Fig. 3.1. Classification of ship compartments according to the nature of flooding:

1 - Category I compartment;
2 - Category II compartment;
3 - Category III compartment.

Flooding of Category I compartments increases the initial stability since the center of gravity of these compartments, in the majority of cases, lies below the actual waterline. The presence of a large number of Category II and III compartments significantly reduces ship's stability. The flooding of compartments of either category increases the mean draft of the ship and decreases her reserve buoyancy. The asymmetric flooding of compartments can cause dangerous heeling and trim.

Determination of ship's trim and stability when a single compartment is flooded. The formulas given below are for Category III compartments. They can also be used for compartments of the other two categories.

Change in mean draft, in meters:

$$\delta T = \frac{v}{S - s}. \tag{3.1}$$

Change in transverse metacentric height, in meters:

$$\delta h = \frac{v}{V}\left(T + \frac{\delta T}{2} - z - \frac{i_{p_x}}{v}\right). \tag{3.2}$$

Change in longitudinal metacentric height, in meters: /64

$$\delta H = \frac{v}{V}\left(T + \frac{\delta T}{2} - z - \frac{i_{p_y}}{v}\right). \tag{3.3}$$

Angle of heel, in degrees:

$$\theta = \frac{v\left(y - y_F'\right)}{V h_1}. \tag{3.4}$$

Angle of trim, in degrees:

$$\psi = \frac{v\left(x - x'_F\right)}{VH_1}. \tag{3.5}$$

Draft at the bow, in meters:

$$T_{H1} = T_H + \delta T + \left(\frac{L}{2} - x'_F\right)\psi. \tag{3.6}$$

Draft at the stern, in meters:

$$T_{K1} = T_K + \delta T - \left(\frac{L}{2} + x'_F\right)\psi. \tag{3.7}$$

where v is the volume of water in the damaged compartment up to the original waterline, m^3;

S is the actual waterplane area, m^2;

s is the area of the water surface (lost area) in the compartment at the waterline level, m^2;

x, y and z are the coordinates of the center of gravity of the water in the damaged compartment, m;

i_{p_x} and i_{p_y} are the lost moments of inertia about the longitudinal and transverse axes, m^4;

x'_F and y'_F are the coordinates of the center of flotation (at the new waterline), m.

Note: If in these formulas the lost area s = 0, then S' = S; $x_F = x'_F$; $y'_F = 0$; and $i_{p_x} = i_{p_y} = 0$; hence, we obtain formulas for the Category I compartment. But if s = 0 and i_{p_x} and i_{p_y} are replaced by i_x and i_y (i.e., by the natural moments of inertia of the free surface of water in the Category II compartment), then we obtain the formulas for the Category II compartment.

If a group of compartments of different category are flooded, the trim and stability of the ship can be determined by the following two methods: the equivalent compartment method and the superposition method (with certain restrictions). /65

The equivalent compartment method amounts to the determination of the parameters and category of the compartment equivalent to the group of those actually flooded and to finding the change in the ship's trim and stability by means of formulas (3.1) through (3.7).

The superposition method reduces to the following:

- the determination of the change in ship's trim and stability caused by the flooding of each of the compartments in the group under the assumption that the rest of the compartments are not flooded; and

- the addition of changes in trim and stability (caused by the flooding of each compartment) for all the compartments.

This method can be used only to determine changes in metacentric heights when Category I and II compartments are flooded and changes in trim angle and draft for Category I compartments.

2. Basic Principles of Righting Damaged Ships

Righting a damaged ship involves eliminating or reducing her heel and trim as well as restoring or maintaining the ship's stability while keeping a check on her reserve buoyancy. It has the following objectives:

- to prevent the loss of the ship as a result of the loss of her stability due to heavy damage;

- to insure the most effective utilization of the ship's weapons and equipment; and

- to restore, to the extent possible, the seaworthiness of the ship.

A ship can be righted as follows:

- by pumping liquid cargoes overboard or by transferring them from one space to another symmetrically located space;

- by counterflooding;

- through a combined method including counterflooding, the transfer and removal of liquid cargoes. /66

From the standpoint of maintaining reserve buoyancy the pumping of liquid cargoes overboard (Fig. 3.2) is the most effective method.

Righting a ship by transferring fuel or water (Fig. 3.3) is equivalent to the removal of loads from one side or end and shifting them to the other side or end. With this method of righting, the reserve buoyancy and draft remain unchanged.

In righting a ship through counterflooding (Fig. 3.4) water is taken inside the ship, a fact which decreases the reserve buoyancy and increases the ship's draft. The primary advantage of this method is that the righting of the ship proceeds rather quickly, a fact which is

of considerable importance since timely control over an increasing heel or trim, together with the partial righting of the ship, can prevent her from capsizing.

The combined method of righting a ship (Fig. 3.5) is used in order to quickly reduce heel or trim. By this method the required number of spaces are flooded with water and at the same time, or somewhat later (for further righting of the ship), liquid cargoes are transferred to the opposite side (or end), or pumped overboard. /67

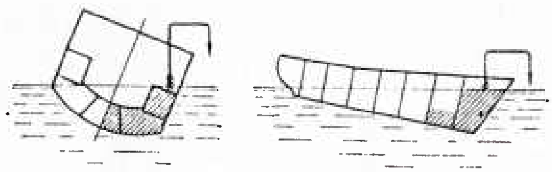


Fig. 3.2. Righting a ship by pumping liquid cargoes overboard

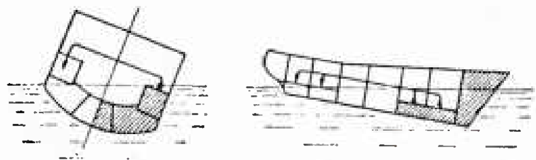


Fig. 3.3. Righting a ship by transferring liquid cargoes

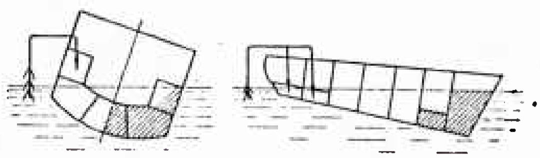


Fig. 3.4. Righting a ship through counterflooding

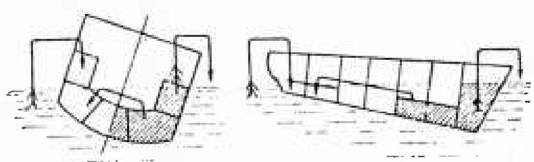


Fig. 3.5. Righting a ship through the use of the combined method

Basic steps in righting a ship:

- in all cases take necessary measures to determine, with maximum accuracy, which compartments are flooded and how;

- right the ship while maintaining the integrity of the freeboard, decks, platforms, and bulkheads so that no additional spaces are flooded through holes in them during righting;

- perform only those operations which can be quickly discontinued, if necessary;

- right the ship with the aid of the side compartments, i.e. counterflood the compartments and transfer or pump liquid cargoes overboard only when the damaged ship exhibits a positive initial stability;

- if the ship sustained heavy damage which resulted in the flooding of a large number of compartments (i.e. in taking a large amount of water), her condition, in terms of the negative initial stability, must be considered as dangerous.

The external indications of the negative initial stability are:

- heeling with symmetrical flooding of compartments;

- sudden rolling of the ship from side to side;

- rolling of the ship from side to side when turning, followed by /68
heeling when the ship returns to the straight heading;

- tendency of the ship to roll over to the opposite side when righted.

To restore the stability of a ship with the negative initial stability the first and foremost measures to be taken are:

- remove the water from decks and platforms by pumping it overboard or by transferring it to low-lying spaces and flooding them completely;

- drain, to the extent possible, the compartments containing seepage water;

- ballast the ship, i.e., take on (or transfer) seawater or transfer fuel into empty bottom compartments until they are completely filled;

- eliminate the overflowing of liquid cargoes from one compartment to another;

The usual methods for righting a ship can be used only after the ship's initial stability becomes positive.

In cases where reliable information concerning flooding of the damaged compartments is lacking, the ship can be righted in stages by selecting compartments to be used in righting in the next stage on the basis of the evaluation of stability of the ship in the preceding stage.

In righting a ship only the minimum possible amount of reserve buoyancy must be expended and no stability must be lost. To achieve this, one should select only those compartments to be used in righting which are located as low as possible beneath the waterline and as far as possible away from the center plane and midsection so that the heel and trim can be decreased simultaneously.

The heel of the ship must be corrected first. The trim is corrected only if absolutely necessary (for example, when the main deck of one of the ends of the ship becomes submerged) since correcting the trim by counterflooding requires considerable expenditure of reserve buoyancy and results in a decrease in the transverse stability due to the incomplete flooding of large compartments.

To facilitate the determination of the trim and stability of a damaged ship and the selection of compartments to be used in righting, one should use the survivability tables which have been compiled for specific displacements of undamaged ships.

3. Ensuring Survivability of a Submarine in the Submerged Condition /69

If water floods the pressure hull of a submarine the following measures must be taken immediately:

- increase the speed of the submarine to the maximum possible;

- rig the diving planes for rising (with or without the trim by the bow), or for diving (with the trim by the stern) and then develop the maximum permissible trim by the stern without letting it go beyond the critical value at which the power plant stops operating;

- blow the MBT's of the damaged end until the trim begins to decrease;

- start up the pumps to drain the damaged compartment;

- if the submarine continues to submerge despite the measures taken, blow the midship MBT's;

- bring the submarine to the surface and while surfacing blow the midship MBT's at a depth of 30-50 m (if they have not been blown before) and the MBT's in the undamaged end; set the diving planes so as to bring the submarine trim to zero and reduce the speed.

- take all measures to repair the damage in the pressure hull.

In order to overcome the loss of buoyancy, which is not accompanied by an increase in trim, it will, as a rule, be sufficient to increase the speed and, at the same time, blow the midship MBT's.

If rising is precluded by the situation on the surface and the submarine has a way on, then it is necessary:

- on rising to a depth exceeding the minimum safe depth by 50-60 m, to set the planes so as to trim the submarine and stop blowing the MBT's;

- on reaching the minimum safe depth, to keep the submarine at this depth by maintaining the speed and trim and by using the planes; if necessary, one may let some air out of the blown MBT's or perform additional blowing; it should be kept in mind, however, that the presence of air in the tanks makes it difficult to maintain the submarine at the required depth; the trim of the submarine must not exceed the maximum permissible value at which the power plant still continues to operate; /70

- to maintain the submarine at the minimum safe depth;

- to take all measures to repair the damage in the pressure hull and drain the damaged compartment.

If the power is lost but the submarine continues to move by inertia or if it is impossible to develop speeds greater than 5 knots, with the water coming inside the pressure hull, it is necessary:

- to rig the planes for rising (with or without the trim by the bow) or for diving (with the trim by the stern) and then to develop the maximum permissible trim by the stern without letting it go beyond the critical value at which the power plant stops operating;

- to blow the MBT's both in the damaged end and amidships at the same time; and

- to surface the submarine.

With the submarine having no way on and with the water flooding the pressure hull, it is necessary to blow the MBT's immediately both in the damaged end and amidships and bring the submarine to the surface without permitting the buildup of the dangerous trim by varying the MBT's blowing mode. With the submarine approaching the surface, blow all MBT's with high pressure air.

With the stern planes of the submerged submarine locked in the position for diving and an increasing trim by the bow, it is necessary:

- to rig the still functioning planes for rising;

- to reduce the speed of the submarine by reversing the main engines without letting the submarine move astern;

- to blow the forward group of ballast tanks until the trim begins to decrease;

- when the trim begins to decrease, to let the air out of the blown tanks (tank) in steps;

- when the trim approaches zero and the speed of the submarine is reduced to the point where it is possible to use the intact planes to compensate for the effect of the jammed ones, to maintain the speed ahead within the limits ensuring control of the submarine.

With the stern planes of the submerged submarine locked in the position for rising, it is necessary:

- to rig the intact planes for diving; /71

- to reduce the speed of the submarine; and

- to start blowing the after ballast tanks (tank), if necessary.

Subsequent steps to be taken in controlling the submarine are similar to those made when the stern planes are jammed in the position for diving. After the trim has been stabilized and the submarine has stopped changing depth it is necessary to compensate for the effect of the jammed planes by ballast trimming the submarine.

When the trim (by the bow or by the stern) begins to increase without the loss of buoyancy, it is necessary to do the following immediately:

- rig the diving planes for rising when the trim is by the bow or for diving when the trim is by the stern;

- blow the MBT's located in that end whose trim is being corrected, if necessary;

- when the trim begins to decrease let the air out of the MBT's being blown;

- balance the submarine while eliminating the cause of the increased trim.

If water enters the diesel compartment when the submarine is snorkeling, immediately give the signal "Crash Diving", which calls for the following steps to be taken:

- close the outside flapper valves and hull valves in the snorkel exhaust and intake pipes;

- stop the diesels and disengage the bow pneumatic clutches;

run the submarine at the medium speed by means of the propulsion motors;

- rig the bow planes for rising and use the stern planes to maintain a 0-3^{o} trim by the stern;

- blow the after and midship MBT's and surface the submarine.

Steps which are taken by the crew of the damaged compartment, without receiving any orders, when the water begins flooding the compartment:

- sound the emergency alarm and report the accident to the central station. If this is impossible, notify the adjacent compartment about the mishap, specifying the rate of the incoming water and the location of the hole in terms of the height of the compartment;

- seal off the compartment;

- turn on the emergency lighting;

- seal the hole allowing the water to flood the compartment by using all the existing means;

- prepare pumping and drainage systems and actuate them; /72

- seal off battery tanks;

- prepare and use escape equipment;

- disconnect flooded electrical equipment and machinery.

Steps to be taken by the crew of undamaged compartments, without receiving any orders when the water begins flooding an adjacent compartment:

- report the accident in the adjacent compartment to the central control station;

- seal off the compartment;

- turn on the emergency lighting;

- start up water removal equipment;

- make damage control tools and materials ready in case they are needed in your own compartment or for transferring to another compartment.

- make underwater rescue equipment ready for use;

- tighten bulkhead stuffing boxes admitting air or water from the damaged compartment;

- disconnect nonpressure tanks and systems in the damaged compartment, experiencing a rise in pressure from nonpressure tanks and systems in the adjacent compartments;

- check tightness of valves in pumping and drainage systems to prevent penetration of air.

Measures to be taken by the crew, on orders from the central control station, when water begins flooding a compartment:

- change the operating mode of the submarine;

- feed high pressure air to the compartment being flooded to create counter air pressure, and to adjacent compartments to support the bulkheads;

- batten down bulkhead doors and other openings in the bulkheads;

- abandon the compartment;

- blow (flood) main and auxiliary ballast tanks;

- release emergency signal buoys or use other means to indicate the location of the damaged submarine (only the Commanding Officer of the submarine or the individual acting for him has the right to issue this order);

- abandon the submarine and rise to the surface.

4. Factors Causing the Increase in Trim and Heel and Methods for Eliminating Them /73

Numbers	Factors causing the increase in trim and heel	Methods for eliminating trim and heel
1	Occurrence of an increasing trim with the simultaneous loss of buoyancy: a) when the submarine is diving:	In all cases where the trim increases during diving

Numbers	Factors causing the increase in trim and heel	Methods for eliminating trim and heel
	- water flooding the pressure hull; - incorrect determination and use of ballast trimming; - undetected flooding of auxiliary and special ballast tanks and torpedo tubes; - untimely blowing of the negative buoyancy tank or incomplete closing of its flood valves;	(immediately after the flooding of the midship MBT's) or when an accident occurs in the submerged condition, resulting in the flooding of the pressure hull, the submarine should surface, if the immediate situation permits, and the cause of the increasing trim should be eliminated.
	b) when the submarine is submerged: - water flooding the pressure hull; - failure to periodically adjust the trim, drain holds and special tanks; - spontaneous flooding of the annular gaps in the torpedo tubes.	If the immediate situation precludes surfacing, then one should deal with an increasing trim in accordance with the instructions given in Part 3, Section 3.1 in this book.
2	The occurrence of an increasing trim without the loss of buoyancy: - improper distribution or consumption of variable cargoes; - loss of control over the diving planes; jamming of planes or control errors; - jamming or icing of vent valves when diving.	/74
3	Occurrence of heel: a) when the submarine is on the surface: - flooding of MBT's on one side due to the leakage of vent valves, flood valves, access holes, fittings, or as a result of damage to the tanks;	When the submarine begins heeling in the surface condition, the cause of the heel must be determined and eliminated and the submarine righted. If several MBT's on one side are damaged, the heel is corrected according

Numbers	Factors causing the increase in trim and heel	Methods for eliminating trim and heel
	- nonuniform blowing of the side MBT's; - flooding of the auxiliary ballast and special-purpose tanks on one side of the submarine; - wrong distribution of variable cargoes and nonuniform consumption of fuel stored in the side tanks; - wave and wind effects;	to instructions on survivability.
	b) when the submarine is diving (because of nonuniform flooding of the MBT's): - incomplete opening of flood valves or vent valves; - nonuniform fouling of flood valve grids (flood holes) with sea shells and sea weed; - icing of vent valves on one side of the submarine; - partial or complete closing of the emergency flap valve on one side of the submarine; - breakdown of the drive of the emergency flap valve or flood valve, a factor which can result in closing of these valves during flooding of the tank when diving;	If an increasing heel arises during flooding of the midship MBT's and the situation permits the submarine to remain on the surface, stop diving and assume the diving trim condition and then establish and eliminate the cause of heeling. If the situation does not permit the submarine to remain on the surface, continue to dive while canceling the positive buoyancy by means of speed and planes. It is prohibited to admit water into the balancing tanks for this purpose. /75
	c) when the submarine is in the submerged condition: - significant leakage of fuel from the side tanks; - nonuniform flooding or draining of interior tanks located along the sides; - formation of an air cushion in the side MBT's;	When a heel occurs in the submerged condition, its cause must be established and eliminated according to the instructions on survivability.

Numbers	Factors causing the increase in trim and heel	Methods for eliminating trim and heel
	- flooding or draining of torpedo tubes and special tanks on one side of the submarine; d) when the submarine is rising: - malfunction of the surfacing system such as leakage of vent valves, fittings, and openings in tanks; jamming or faulty vent valve controls, etc.; - damage to the shells of some of the MBT's located on one side of the submarine, resulting in the loss of their airtightness; - slow flow of water from the superstructure during surfacing of the submarine; - partial loss of transverse stability when the submarine surfaces with a large excess of buoyancy and no way on; - wind and wave effects on the submarine.	 The heel occurring during blowing of the MBT's with low pressure air must be controlled by means of vent valves; it should not be allowed to exceed 5°.

/76

Section 3.2. Firefighting

1. Regulations for Extinguishing Fires

The following steps are taken by the crew when fighting fires:

- alerting personnel about the fire;

- preparing firefighting equipment;

- turning off electric power in the area of fire; /77

- extinguishing fire;

- coping with smoke;

- removing charred materials from the site of fire after fire has been extinguished.

Fire in magazines is extinguished with water by using sprinkler or flooding systems. The individual making the decision to use these systems must immediately take measures to evacuate personnel from the area and notify, as soon as possible, the central control station and control stations of the gunnery and engineering departments about the flooding or spraying of the magazine and the reasons for taking such action. The hatches must be opened while extinguishing fires in magazines. Since powder does not require air for burning, it is extinguished by removing heat, i.e. by using water alone. Rocket fuel is extinguished by using special fire-extinguishing fluids.

Fighting of ammunition fires on the main deck is carried out in accordance with special regulations. In addition, the following must be done:

- open, if possible, all handholes in mine or torpedo shells and cool the latter either with water from hoses or with wet mats or carbon dioxide from fire extinguishers;

- roll away or remove to a safe distance any ammunition located nearby;

- extinguish the fire around burning ammunition.

If it is impossible to roll or carry away the ammunition quickly from the fire, the spreading of heat and flames must be stopped by using a water curtain while the ammunition itself must be cooled by pouring water over it.

When a ship is underway in formation at sea, burning ammunition should be jettisoned and other ships informed of this action.

Burning ammunition may not be extinguished with chemical or high-expansion foam, carbon dioxide, steam, fire-extinguishing fluid, sand, or by sealing off compartments.

Fuel and lubricating materials are extinguished as follows:

- in closed spaces--by using saturated steam delivered through the fire-fighting system;

- in open or damaged compartments--by using foam or carbon dioxide from fire extinguishers;

- on decks and in holds--by using foam from foam generators, foam /78
monitors and foam fire-extinguishers as well as by using sand and mats;

- light fuel is extinguished by using special fire-extinguishing fluids from stationary installations.

Fires in engine and boiler rooms are extinguished with steam, by spraying water, and using special fire-extinguishing fluids.

A fine water spray should be used to extinguish fuels and lubricating materials. Continuous water jets may be used only when one is sure that the water would not splash the burning liquid and create new fires.

If fuel or lubricating materials have ignited overboard with the ship dead in the water, at anchor, or moored, the burning fuel must be driven off by jets of water from fire hoses and, if possible, the ship put underway heading into the wind.

When extinguishing burning electrical equipment one must first disconnect it from its power supply.

Burning live electrical equipment may be extinguished:

- with high-expansion foam prepared in special appliances by using fresh water;

- with distilled or fresh water whose salinity is no higher than 10°/oo Br.

- with carbon dioxide from hand fire extinguishers (for extinguishing small fires);

In extinguishing burning live electrical equipment with distilled and fresh water or with high-expansion foam using fresh water, personnel must wear insulated gloves. The use of chemical fire-fighting foams, fluids, and seawater to extinguish live electrical equipment is prohibited.

Burning de-energized electrical equipment may be extinguished by using any fire-fighting equipment; however, to avoid damaging the electrical equipment, carbon dioxide should be used first. If it is unavailable, then asbestos mats, high-expansion foam and fresh water may be used.

If the situation permits, the ship should be turned toward the /79
wind when fighting fires on open decks so that the fire would be blown away from the ammunition, fuel and combustible materials, which, when ignited, can contribute to the spreading of the fire. It is recommended that fires on open decks be extinguished by means of continuous water

jets directed at them leeward, if possible. At the same time, to limit the spread of fire, ship structures, boats, ammunition, fuel and lubricants, etc., in the vicinity of the fire must be cooled with water. Fires inside superstructures should be extinguished with foam and sprayed water.

2. Firefighting Measures

Magazines are potential centers of explosions and fires. Therefore, careful and systematic monitoring of temperature and humidity is one of the basic fire-fighting measures.

In magazines with ammunition it is absolutely prohibited:

- to use an open fire;

- to carry firearms, explosives, matches, and igniters;

- to install unauthorized electrical wiring;

- to use portable electric lamps, electric drills, electric fans, and electric heaters;

- to store any objects other than the authorized equipment and ammunition.

Electric lights in magazines must be placed in sealed fixtures, and their switches must be located outside the magazines.

If the temperature in the magazine becomes higher than $+30^{\circ}$, measures must be taken to reduce it by means of the ventilation system. If the temperature cannot be reduced, the magazine should be sprinkled (or flooded). As a rule, the flooding or sprinkling of magazines containing ammunition is conducted only by order of the Commanding Officer of the ship.

Before loading or unloading ammunition on the ship general quarters is sounded. During the loading and unloading of ammunition the ship must be ready to get underway immediately. A watch is posted at the helm, capstan, main engines, flood valves and mooring lines (both aboard ship and at the pier); damage control parties must be in the condition of readiness No. 1, and the rest of the ship's company--in the condition of readiness indicated by the Commanding Officer of the ship. A fire- /80
safety watch must be posted at stations where danger from fires and explosions is the greatest.

The temperature of liquid fuel must be constantly monitored and should not exceed $+50^{\circ}C$ for heavy (dark) grades and $+25^{\circ}C$ for light

grades of fuel.

All liquid fuel tank openings and fuel lines must always be closed, with no fuel leaking from them. No open fire may be kept nearby while opening fuel tanks and dismantling fuel lines.

Gasoline, kerosene, and other highly inflammable substances must be stored in special containers in well ventilated places far removed from any sources of fire, as prescribed by ship regulations. The rules governing prevention of fires in these areas are the same as those applicable to magazines containing ammunition.

When taking on fuel and lubricating materials a watch must be posted at the valves (aboard the tanker or at the pier) as well as at the tanks that are being filled and the working pressure must continuously be maintained in the fire main.

To prevent the outbreak of fire in the immediate vicinity of the ship's anchorage the following measures must be taken:

- remove oily rags, refuse, and other combustible materials from the ship and take them to locations on the shore set aside specifically for this purpose;

- install fire-fighting equipment stations on piers.

The pumping of fuel oil, solar oil, lubricating oil and other combustible liquids overboard at the site of anchorage is prohibited.

3. Firefighting by the Submarine Crew

Damage control measures which require no separate orders for the crew and which the crew of the damage compartment takes routinely during sudden fire outbursts, fires, emergencies involving ammunition, sputtering of oil, appearance of oil mist or smoke are:

- sounding the emergency alarm in the compartment and reporting this immediately to the central control station; if that is impossible, alerting the adjacent compartment about the location and nature of the emergency; /81

- de-energizing burning electrical equipment with the exception of the electrical equipment used in the propulsion and handling of the submarine, and reporting this immediately to the central control station;

- discontinuing storage battery charging;

- stopping both the central ventilation system and the separate

ventilating system serving the compartment and storage battery;

- sealing off the compartment, closing trunks, flap and gate valves, with the exception of the trunks delivering air to the diesels; these trunks are closed at the same time the diesels are stopped; bulkhead doors must be secured with rack or wedge locks (not only with spring catches);

- stopping the diesels when there is a fire in the diesel compartment and reporting this immediately to the central control station;

- sealing off the storage battery wells;

- turning on the emergency lighting;

- stopping the operation of air regeneration equipment;

- putting on and setting the self-contained oxygen breathing apparatus in the "ready" position; the breathing apparatus is turned on by order of the compartment officer and this action is reported immediately to the command control station. The use of the breathing apparatus and of the gas mask in an open fire area is prohibited.

- moving of combustibles, explosives and regenerative materials away from ignition sources;

- closing the vents of oil tanks;

- disconnecting hydraulic system components during sputtering of oil through leaks and damaged hydraulic chambers in these components; disconnecting actuators for the rudder and diving planes by order from the central control station.

Other measures taken by the crew during the outbreak of fires in the compartment with ammunition:

- covering undamaged mines and torpedoes with wet canvas, blankets, and other materials at hand and saturating them with water;

- removing boxes (containers) with detonators and primers from the compartment;

- opening the bottom covers of the torpedo and access hatches when evacuating the crew from the compartment.

Damage control measures which may be taken by the crew of undamaged compartments without receiving any orders during sudden fire outbursts, /82 fires, emergencies involving ammunition, sputtering of oil, appearance of an oil mist or smoke are:

- reporting the damage in the adjacent compartment and its nature to the central control station;

- sealing off compartments; closing trunks, flap and gate valves, with the exception of the trunks delivering air to the diesels; these trunks are closed at the same time the diesels are stopped;

- discontinuing storage battery charging;

- turning off ship's ventilation system;

- checking the readiness of the stationary fire-extinguishing equipment;

- making the portable firefighting equipment ready for delivery to the damaged compartment or to the adjacent compartment, as required;

- disconnecting the damaged electrical equipment from its power supply, except for the electrical equipment used in the propulsion and handling of the submarine;

- monitoring and eliminating any possible leakage of toxic gases and smoke;

- turning on the emergency lighting;

- putting on and setting the self-contained oxygen breathing apparatus in the "ready" position; the breathing apparatus is turned on by order of the compartment officer whenever leakage of harmful gases or smoke is detected and when preparing to receive personnel from the damaged compartment, with an immediate report made to the command control station.

Damage control measures taken on order from the command control station during sudden fire outbreaks, fires, emergencies involving ammunition, sputtering of oil, appearance of an oil mist or smoke are:

- disengaging and switching the equipment used in the propulsion and handling of the submarine;

- blowing the main ballast tanks;

- opening bulkhead doors and evacuating all hands from the damaged compartment, except in those cases where the fire has developed so rapidly that this decision may be made independently by the compartment officer;

- releasing high pressure air overboard;

- equalizing the pressure, opening, examining and ventilating the compartment;

- taking all damage control measures resulting in partial or total loss of ammunition or making it less usable, including the jettisoning or discharging of damaged ammunition; flooding of annular spaces in the torpedo tubes and flooding of spaces containing primers.

Section 3.3. Providing Life Support to the Crew Aboard a Damaged Submarine /83

In the presence of harmful gases in the compartments of a submerged submarine the air purification equipment must be turned on and the cause of the penetration of gases eliminated. If the concentration of gases continues to increase even after the air purification equipment was turned on, the personnel who are not on duty at the battle stations should be evacuated and all others should begin using the self-contained oxygen breathing equipment.

If gas appears in a compartment when the submarine is on the surface or snorkeling, the damaged compartment must be thoroughly ventilated, discharging the contaminated air to the atmosphere or to the diesel compartment. Personnel are permitted to enter the damaged compartment without the use of the breathing apparatus only after the air of the compartment has been completely cleaned.

It is prohibited to mix together the air of a contaminated compartment with that of other compartments or to discharge it into adjacent compartments.

Spilled mercury in a compartment must be reported immediately to the commanding officer of the submarine. The crew must be evacuated from the compartment, and the compartment sealed off and demercurized. Demercurization is done while using the self-contained breathing apparatus. The mercury should be gathered up with copper wire brushes dipped in acid, and then shaken off in a glass container.

If the mercury got into the hold and it is impossible to remove it, the hold must be partially flooded with water so as to prevent the evaporation of mercury.

The period of time that the crew may safely remain in dry compartments with normal air pressure--without taking into account the operation of the air regeneration equipment (i.e., ventilation of the compartments) and with no harmful gases present in the compartment--can be determined from the fact that one cubic meter of air insures the survival of one person at rest for two hours. Here the critical norms are: the accumulation of carbondioxide up to 6-7% and the /84

reduction in oxygen down to 12-14%. It should be kept in mind that the effect of carbon dioxide on personnel manifests itself sooner than does the oxygen deficiency.

When the air pressure of 6 to 10 kg/cm^2 is developed in dry compartments to reinforce the bulkheads in a damaged compartment, personnel must use the oxygen breathing apparatus. In such a case the length of time that the personnel can remain in the compartment will be governed by the length of the breathing apparatus operation time.

The permissible time that personnel may remain in compartments with increased pressure in the absence of air regeneration depends on the accumulation of carbon dioxide and its partial pressure in the compressed air of the compartment.

In making a decision concerning unassisted escape of personnel in the underwater escape gear from compartments with increased pressure it is necessary to bear in mind that the individual escape is possible only when the time spent in compartments under a pressure of up to 6 kg/cm^2 did not exceed 40 minutes or under a pressure of 10 kg/cm^2--15 minutes. For these periods of time spent under pressure the decompression procedures have been developed for personnel escaping by using buoy lines. If the time spent under pressure exceeds that indicated, the rescue of personnel is carried out by the rescue party.

The length of time personnel may remain in the water in flooded compartments without dry suits depends on the temperature of the water. At $0^{\circ}C$ it is 15 min; at $10^{\circ}C$--60 min; and at $20^{\circ}C$--up to 7 hours. The use of dry suits and diver's underwear prevents overexposure to cold and makes it possible to remain in cold water up to 5 hours.

To prolong the life of personnel in a sunken submarine all measures must be taken to maintain the following concentration of gases:

- carbon dioxide, no higher than 1.5%;

- oxygen, no lower than 18%.

To prolong the stay of personnel in compartments of a submarine the following measures must be taken:

- personnel must wear warm underwear;

- personnel not engaged in damage control must be allowed to rest in bunks;

- only the most urgent jobs should be performed aboard a submarine with a minimum number of personnel participating;

- reduce food rations: drinking water per person, up to 9.5 liters per 24 hours and food products, 3 to 4 times less than the daily allowance.

To improve the effectiveness of the air regeneration equipment, when the temperature of the air becomes lower than +10°C and its absolute humidity drops, the air regeneration equipment must be placed in the upper part of the compartments with the personnel staying in its immediate vicinity.

CHAPTER 4

HANDLING A SUBMARINE

Section 4.1. Surface Handling /86

A twin-screw submarine with both engines running ahead answers the helm well. When one engine is operating ahead the submarine turns faster in the direction opposite to the operating engine rotation and has a smaller turning diameter.

A submarine moving astern answers the helm poorly and is kept on course only by means of the engines. She answers the helm well only when she moves by inertia with the engines stopped.

To turn the submarine in her own water the engines must be opposed, i.e., the inside engine must be running ahead and the outside engine astern, with the rudder hard over in the direction of the turn. In order to turn in her own water in fresh breeze the engines must be opposed and running at a moderate speed.

In heavy seas the most favorable courses are those heading directly into the waves and running with the waves or close to them (up to 30°). If the bridge is swept by the sea with a considerable amount of water getting into the control room, the speed of the submarine should be reduced. Personnel standing watch on the bridge should secure themselves for stormy seas. They may go out on deck only with the permission of the Commanding Officer. Each man going on deck must wear a life jacket and use a safety line.

When a submarine is at sea the sea valves may be opened and machinery started up only by order of the Commanding Officer (or the officer of the watch). Under certain conditions, determined by the Commanding Officer or the watch officer of the submarine, a special watch is posted at the drives of open trunks and hatches.

When at sea it is prohibited to hang articles of clothing, binoculars, etc., on the bridge or to extend lines and cables across the sail hatch. The bridge must always be ready for crash diving. /87

The seaworthiness and maneuvering characteristics of a submarine in the diving trim condition are somewhat inferior to those in the full buoyancy condition. A submarine underway, especially in a seaway, tends to pitch forward and when turning, she becomes aft heavy so that part of her aft superstructure goes under water.

When operating in the diving trim condition the trim should be closely watched. If the submarine tends to pitch forward, the speed

should be reduced and the forward group of tanks blown, or else maintenance of the diving trim discontinued.

The transition from the full-buoyancy to the diving trim condition should be made with no way on or at low electric motor speeds. First, however, personnel not required on the bridge should be removed, the negative buoyancy tank blown, the stern diving planes set for surfacing, the general alarm sounded, and the crew should be ready to batten down the sail hatch. It is categorically prohibited to change from the full-buoyancy to the diving trim condition with the submarine diesels running and trunks open.

Section 4.2. Trimming

The submarine trimming requirements are:

- the residual buoyancy must be equal to zero or be close to it;

- the trim by the bow must not exceed 0.5 to 2°; the amount of water in trim tanks must be one-half to three-fourths of the volume of each tank;

- the trimming must be stable for the given operating mode submerged during the period of one watch (4 hours);

- the deflection of the stern diving planes must not exceed $\pm 5^{\circ}$ when the bow planes are in the plane of the frame;

- if, upon surfacing, it is necessary to dive again after a short interval of time, the submarine should be able to maneuver freely under water without trim adjustment.

In a calm sea a submarine is trimmed at the periscope depth while in a seaway it is trimmed at the safe depth. After personnel have /88
taken their stations in accordance with the diving regulations the sail hatch is battened down, the submarine moves at a low speed developed by the electric motors, and the main ballast tanks are flooded. At the end of flooding the command is given "Trim the submarine at a depth of so many meters, at such and such a speed, and the bow or stern down so many degrees."

The assigned trimming depth is maintained with the aid of speed and trim. When diving to this depth a large trim should not be created. The vents of the main ballast tanks are closed immediately upon reaching the prescribed depth after changing the trim from the bow to the stern.

If the submarine does not dive, water must be taken into the variable

tank. As soon as the depth gauge indicates that the depth is changing, taking water in must be stopped.

If, after flooding the midship tanks, the submarine acquires negative buoyancy, a trim by the stern must be created by means of the planes and speed and, while maintaining the depth, the water must be pumped out of the variable tank. If these measures are inadequate, a bubble must be admitted into the midship group of tanks or the tanks must be blown; or the required amount of water must be pumped out of the variable tank and then, after removing the bubble from the midship group of tanks, trimming is continued. These measures are taken depending on the rate at which the submarine changes her depth.

In order to remove air bubbles from the end main ballast tanks the vent valves must be opened and a trim created alternately by the bow and stern ("rock" the submarine), after which the vent valves of the end main ballast tanks are closed.

By draining or taking water into the variable tank and by distributing the auxiliary ballast among the trim tanks a situation is achieved in which the bow planes are at zero, the stern planes deviate slightly from the plane of the frame, and the submarine maintains her depth with a slight trim by the bow. In such a position the submarine is considered to be trimmed.

After trimming the submarine the vent valves of the midship group of tanks must be opened to force out the remaining air cushion and then closed. After maintaining the trim of the submarine at zero degrees for a certain period of time a command "trimming completed" is given. With this command the compartments report to the control room on the presence of personnel in them and on the amount of water in the auxiliary ballast tanks for making the appropriate entries in the deck and trim logs.

Section 4.3. Handling a Submarine When Snorkeling /89

A submarine changes from the full submergence to the snorkeling mode of operation after the signal "general quarters" has been given.

Before changing, the command "Trim the submarine at a depth of so many meters" is given. The change to the snorkeling mode is made upon the completion of the trimming.

During changing, the additional hydrodynamic forces and moments arise altering, to some extent, the equilibrium of forces and moments, a fact which requires an appropriate adjustment of the diving planes in order to compensate for these forces.

After starting the diesels and reaching the prescribed pressure in the gas-exhaust system, the upper (double-action) snorkel gas flapper valve opens, water is removed from the gas line and the submarine acquires positive buoyancy. In order to reduce the buoyancy to zero an appropriate amount of ballast must be taken into the variable tank. The transition from small to large engine loads is carried out gradually.

When operating in the snorkeling mode, one should make sure that the float valve is not submerged. In a seaway, when the planesman is unable to maintain the operating depth accurately, the snorkel air intake pipe may take in water. In such a case the float valve closes causing a sharp reduction in pressure inside the submarine.

When a high vacuum occurs it is necessary to stop the diesels and change to the full submergence mode using electric motors while rising to periscope depth.

After changing to the full submergence mode the submarine acquires negative buoyancy because of the gas line flooded with water. In order to reduce the residual buoyancy to zero an appropriate amount of ballast should be pumped out of the variable tank.

Snorkeling is discontinued on command "Crash dive."

Section 4.4. Submerged Handling /90

1. Submerging and Changing the Depth

In the initial period of submergence the bow planes are rigged for dive and the stern planes for rise. Upon reaching the depth at which all the MBT's have been flooded, the stern planes are set for dive and, depending on the submarine class, a trim up to 10° is created and maintained while diving.

If the submarine is to remain at periscope depth, the negative tank is blown at a depth equal to one-half of the periscope depth. If it is necessary to move to a depth safe from ramming, the tank is blown at a depth equal to or greater than periscope depth.

If, when diving, a trim develops quickly, exceeding the permissible trim, the end MBT's must be blown. In case of loss of buoyancy (due to the inaccurate load calculations or delayed blowing of the MBT's) the midship MBT's should be blown.

Changing the depth of submergence should be accomplished by creating a trim and using speed and buoyancy. For a rapid change in depth the bow planes should be set for dive (or surface) and the stern planes should be used for maintaining the required trim. When approaching the

required depth the submarine should be slowed down with the aid of the stern planes. The bow planes are placed at zero or, if the need arises, they are set for surface (or dive).

To accelerate the submarine submergence the negative tank should be flooded when evading ramming or when the submarine is thrown to the surface by the sea and is unable to submerge with the aid of speed alone.

2. Handling a Submarine in Fresh Weather and When Turning

A submarine operating at periscope depth in fresh weather (with a sea state of 4-5) must, depending on her class, have a negative buoyancy of 3-5 tons, no less than medium speed, and a trim of 1-2° by the bow. Courses with beam on to the sea are recommended.

In cases where it is impossible to remain at periscope depth because of heavy seas the submarine should operate at the safe depth. /91 When rising to periscope depth, it is necessary to have the speed at which the submarine is maintained at periscope depth and to take precautionary measures to avoid ramming.

If the submarine is thrown to the surface in heavy seas, driving her to the required depth is accomplished by increasing her speed, creating a trim and flooding the negative tank. The latter is quickly blown upon reaching a depth somewhat greater than periscope depth.

When turning, the submarine is trimmed by the stern. It is impractical to adjust her trim at this time. In order to maintain the required depth while turning, the planesman must be reminded before making the turn about the shifting of the rudder and placing the bow and stern planes for diving so that the bow planes have a somewhat larger angle than do the stern planes. If, however, the submarine begins to rise, the speed must be increased and the negative tank flooded. The latter is blown as soon as the submarine begins to dive.

3. Handling a Submarine When Surfacing

Before surfacing, orders are given to inspect the surrounding area with the sonar operating in the listening mode and to make one of the diesels ready for blowing the ballast tanks.

After these orders have been executed, on command "Rise so many meters with a trim of so many degrees" the planes operator begins surfacing. During surfacing a small trim is created by the stern and the submarine rises, with the aid of speed and planes, to a depth equal to one-half of the periscope depth. At this depth the midship group of tanks should be blown and their flood valves closed.

When it is clear from the depth gauge that the midship tanks have been completely blown, the flood valves closed, and that the fore and aft superstructures have surfaced, one should open the upper sail hatch, go up to the bridge, examine the submarine and evaluate the situation. In case of heavy seas a bubble should be admitted to the forward MBT group and the stern planes set for surfacing.

Then, on command "Blow the ballast" one should open the air supply trunk to the diesel and the diesel should be started for blowing the ballast tanks. The main ballast tanks should be blown in accordance /92
with the instructions on diving and surfacing. The negative tank should be flooded at the beginning of the blowing of the main ballast tanks. Upon completion of the blowing both the prescribed level of combat readiness and the number of the next watch entering on duty are announced.

4. Emergency Surfacing

Emergency surfacing is resorted to in the event of a significant loss of buoyancy associated primarily with the entry of water into the submarine and tanks located in the pressure hull, or when the trim increases dangerously. Emergency surfacing is accomplished by blowing the ballast tanks with high pressure air.

If the loss of buoyancy is not accompanied by an increase in trim, then the midship tanks must be blown, the speed increased to full speed and the diving planes set for surfacing. If these measures are inadequate, the end MBT's should be blown. When the loss of buoyancy is accompanied by a rapid increase in trim, a bubble must be admitted both into the midship tanks and the appropriate end group of tanks. It should be noted that if the trim increases by the bow the submarine must move full speed astern. If the trim increases by the stern, however, the submarine must go full speed ahead. In all instances of buoyancy loss water from the variable tank and that entering the submarine must be pumped overboard.

5. Handling a Submarine When the Diving Planes Break Down

In all instances where the diving planes break down the trim of the submarine must be adjusted. If the bow planes rigged for surfacing are jammed seawater must be taken into the forward trim tank and the submarine handling continued with the stern planes. If the bow planes are jammed in the diving position, some water should be pumped out of the forward trim tank. When the stern planes are jammed, the trim must be adjusted and handling of the submarine continued with the bow planes. If the stern planes are jammed in the diving position some /93
seawater must be taken into the stern trim tank. If they are jammed

in the surfacing position the water must be pumped out of the stern trim tank.

If both the bow and stern planes break down the submarine is maintained at the prescribed depth by changing the buoyancy, speed or by using the depth stabilizer. In order to create positive buoyancy and level off the submarine whose trim increases rapidly, both the appropriate main ballast tanks and the midship tanks must be blown. In addition, with an increase in trim by the bow the submarine should move full speed astern and with a trim by the stern, full speed ahead. If the trim by the stern increases while the submarine moves ahead, then, in the event of a rapid rise of the submarine, the negative tank must be flooded.

4.5. Handling a Submarine Under Special Circumstances

1. Handling a Submarine when Bottoming and Rising from the Bottom

Bottoming with no way on. After personnel take their stations on command "Stand by, take her down to the bottom," a slight negative buoyancy is created, the submarine is trimmed up to 2° by the bow, and the electric motors are stopped. The submarine should move down slowly. If the downward motion stops, some seawater must be taken into the variable tank. The time when the submarine touches the ground is determined from the depth gauge and fathometer measurements and from the submarine becoming stern heavy.

In bottoming at great depths the submarine acquires the additional negative buoyancy from the pressure acting on the hull, resulting in a greater rate of descent. In order to decrease the descent rate some water must be pumped out of the variable tank.

Bottoming with way on. After personnel take their stations for bottoming, a slight negative buoyancy must be created, the submarine must be trimmed up to 2° by the bow and moved at a low speed. Ten to fifteen meters from the bottom the electric motors should be stopped and the submarine, with a trim either by the bow or close to zero, should move down slowly.

The moment at which bottoming occurs is indicated by light bumps and scraping sounds coming from the outside, the fathometer and depth gauge readings, and by the submarine becoming stern heavy. In order /94
to keep the submarine stable on the bottom, water must be taken into the variable tank.

2. Handling a Submarine When Bottoming on a Density Layer

Bottoming with no way on. When entering the area with a density

layer the motors should be stopped and a slight negative buoyancy created so that the submarine would submerge slowly. Indications that the submarine has reached the density layer are: stopping of the depth gauge needle and the reduction of the trim.

Bottoming with way on. The submarine should move at a low speed, a slight trim must be created by the bow (or stern) and the depth gauge carefully monitored. Indications that the submarine has reached the density layer are: stopping of diving and the reduction in trim, when the submarine is diving, or the accelerated rise and the increased trim, when rising. When the submarine reaches the density layer her motors should be stopped and she should be allowed to level off. While at the density layer, the depth gauge needle and trim must be carefully watched so as to ensure readiness of the submarine to get underway at any moment while maintaining the operating depth. In order to move the submarine from the density layer her motors should be running at low speed, a slight trim by the stern (or bow) must be created by means of the diving planes and the submarine should rise (or dive) to the required depth.

3. Handling a Submerged Submarine when Anchoring and Weighing the Anchor

To anchor with no way on one should:

- select an anchorage site;

- have the submarine trimmed slightly by the bow;

- pay out the anchor chain by means of the electric motor so that its scope is equal to the difference between the depth of the sea and that at the anchorage; and

- create a slight negative buoyancy by taking water into the variable tank to make the submarine move down slowly.

As soon as the anchor reaches the bottom the submarine will become trimmed by the stern and will acquire positive buoyancy. In order to reduce it somewhat a small amount of seawater must be taken into the bow trim tank. The depth of anchorage is varied by veering in or letting out the anchor chain and maintaining the trim of not more than a few degrees. /95

To anchor with the submarine having way on one should:

- dive to a depth exceeding the anchorage depth by 5-10 meters;

- adjust the trim so that with a speed of 2-3 knots and zero trim the submarine would maintain the required depth;

- let out the anchor chain by means of the electric motor upon the arrival at the site of anchorage;

- stop the motors when the distance between the anchor and bottom is about 10 meters and let the submarine move down slowly by inertia.

As soon as the anchor reaches the bottom the trim by the bow of the submarine will increase due to inertia. If there is no inertia, the trim by the stern will increase. Subsequent steps are similar to those taken when anchoring a submarine with no way on. In order for the submarine to get underway a slight trim by the stern should be created and, while pumping water out of the forward trim tank, the anchor should be weighed without permitting the development of large trims by the bow. As the anchor breaks the ground, the submarine should become bow heavy. After at least one-third of the anchor chain has been taken in, the submarine should get underway in order to maintain the required depth.

CHAPTER 5

HANDLING A SURFACE SHIP /96

Section 5.1. Handling a Ship Under Special Circumstances

1. Navigation in Foul Weather

When relieving the watch the officer of the watch must familiarize himself with the weather conditions and weather forecasts. He must also be fully aware of the measures to be taken aboard ship in the event of freshening of the weather or the approach of tropical cyclones (typhoons, hurricanes).

During navigation in foul weather a ship may encounter the following most hazardous phenomena: resonant rolling, reduced transverse stability, and slamming. Resonant rolling occurs when the period T_1 of free rolling of the ship becomes equal to the apparent (observed) period of the wave τ'. Rolling in which $0.7 < T_1/\tau' < 1.3$ is considered to be heavy.

The closer the midsection of the ship is to the crest of the wave the smaller the righting moments acting on the ship when rolling. A prolonged riding the crest of a wave may cause a ship to capsize. The loss in stability is observed when the length of the wave is greater than or equal to the length of the ship at the waterline, i.e., when $\tau \geqslant L$. The danger period for a ship to remain in a state of reduced stability is defined by the condition $\tau' \geqslant 2T$.

Slamming refers to heavy impacts by waves against the forward part of ship's bottom during storms, given an unfavorable set of conditions involving the wavelength and the ship's course and speed. The most heavy slamming is observed when $\tau \approx L$.

Under specific conditions of navigation the parameters of ship's motion (course and speed) that are dangerous in a given situation are determined from the special graphs. For example, the universal graph by Yu. V. Remez makes it possible to determine the following: /97

- course and speed under which the ship experiences resonant (the most dangerous) rolling:

- courses and speed ranges in which the ship experiences heavy rolling;

- course and speed under which the ship is in the most dangerous condition of reduced transverse stability;

- courses and speed ranges in which a reduction in transverse

stability occurs;

- course and speed under which the ship experiences slamming.

The use of the graphs acquires a special significance when it is required to change the course and speed in order to avoid dangerous phenomena or to pass through them in the shortest time possible. If a heterogenous group of ships are sailing in formation the graphs make it possible to select the optimal course and speed so as not to endanger individual ships.

Turning onto a new course in foul weather is a critical and dangerous maneuver. In order to avoid accidents the crew must be informed over the ship's general announcing system before making the turn.

When turning downwind (with the sea) the speed should be increased in order to pass quickly through the "beam onto the sea" position. The subsequent speed must preclude the ship's resonant pitching, avoid the propellers and rudder coming clear out of the water and receiving damage, and preclude heavy impacts of waves against the ship's counter.

Turning upwind (into the sea) is usually complicated by the unfavorable effect of the wind and waves. As a result, the ship loses a considerable amount of speed and the bow crosses the wave line with difficulty. Also, the ship can begin to roll considerably because of the wind and waves, when turning. Therefore, it is recommended that turning upwind begin at moderate speed and then be accelerated. Large turns should be executed in steps of 20-30° with small rudder angles.

2. Handling a Ship with Damaged Steering Gear and Propulsion System /98

A twin-screw ship can be handled with the engines if the rudder is damaged. If the steering gear breaks down and the ship is handled from the main control station, control must be transferred immediately to one of the emergency control stations. When sailing in formation the "I lost steering" signal should be hoisted in order to leave the formation and stop the engines, as the situation requires. If the steering gear goes out of order when the ship is in restricted waters, then, in order to avert an accident, the engines must be run full speed astern, stopped and the ship anchored.

One should bear in mind that, as a rule, the twin-screw ship with a malfunctioning rudder put at a certain angle is far more difficult to handle than a ship without a rudder or with a rudder set amidships.

In order to keep a twin-screw ship with a malfunctioning rudder amidships on a straight course both screws must rotate at the same speed. The effect of wind and waves on the ship should also be taken

into account. With the wind abeam the leeward engine must rotate somewhat faster than the windward engine.

The speed of rotation of the screw should not be changed sharply when the ship veers off the straight course. It is recommended that one engine be rotating with a constant speed and the other be used to maintain the ship on the given heading by either increasing or decreasing the speed of the engine.

If the rudder is jammed at an angle of 5^{o} the ship can be kept on a straight course by means of the engine rotating in the direction corresponding to that of the rudder. If the rudder is jammed at an angle of 10^{o} or more the engines must be run opposed, so that the engine rotating in the direction of the rudder has a speed ahead 1.5-2 levels greater than that rotating astern.

Triple-screw ships with a damaged steering gear can also be controlled by means of the engines. In this case it is better to rotate the center screw at a constant speed and use the side engines to keep the ship on a straight course or execute turns by increasing or decreasing their speed.

The operation of the center engine is not recommended if the rudder /99
is jammed at some angle, since the screw race effect only impedes maneuvering of the ship.

In individual cases, due to the large angle at which the rudder is jammed or due to the damage to the bow, the ship cannot be handled when moving ahead. In such cases the engines must be rotated astern.

In handling a ship moving astern the following special features should be taken into account:

- the ship is very sensitive to the propeller discharge and the effect of the rudder on the controllability is weakened considerably;

- the large sail area of the bow tends to turn the ship toward the wind by the stern;

- while sailing on an even keel the turning circle diameter of a ship moving astern is significantly greater than that of the ship moving ahead (when using the steering gear);

- the trim by the bow improves considerably the controllability of a ship moving with the wind and, conversely, impedes greatly the controllability of a ship moving into the wind;

- the stern of the ship is less adaptable to the effects of the sea, a fact which must be taken into account when sailing in a seaway;

- the lights of a ship moving astern for a prolonged period of time should be rearranged accordingly.

Damage to the propulsion system results in changes in speed and the turning circle diameter but does not preclude the ship from heading in the given direction. To continue motion ahead the rudder must be set at a certain angle in the direction corresponding to that of the operating engine. The rudder position at which the ship is maintained on a straight course is then considered to be the new "zero" position.

When making a turn the ship describes a smaller turning circle in the direction of the damaged engine and a larger one in the direction of the operating engine. When it is necessary to reverse the course or to make a sharp turn in a tight situation with not enough room for maneuvering, it is best to drop anchor and turn with the aid of the anchor.

3. Navigation in Ice Without an Icebreaker /100

When approaching a zone in which the probability of encountering ice is high, visual and electronic observations must be intensified. The approach of ice is characterized by the following external signs:

- lowering of water and air temperatures;

- appearance of ice floes;

- increase in refraction which sometimes makes it possible to detect ice at a distance greater than the visibility range;

- appearance of the so-called "ice blink", i.e., bright spots produced by reflection from ice on the lower clouds, visible at great distances.

The radar detection range of the ice ledge depends on the age and compactness of ice. Various forms of young ice are, as a rule, scarcely visible on the radar screen. However, compact ice is usually detected at a distance of 2-3 miles whereas pack ice, hummocked ice fields and individual ice formations are detected at greater distances. Large fields of level ice and low icebergs do not always produce images on the radar screen. Therefore, to move to an ice region at night or under low visibility is not recommended. When ice cannot be avoided an attempt may be made to pass through if it can be done by the given type of ship.

Before entering an ice region the engineering officer (or the engineering watch officer) should be alerted. He should arrange for the careful monitoring of the operation of the engines. At the same time a watch consisting of damage control personnel should be posted in the forward compartments to monitor the condition of ship's hull.

When navigating in ice the electromechanical system may, because of the excessive thrust, be damaged (melting of the main thrust bearings). Also, because of the excessive torque, twisting of the shaft line or breakdown of the reduction gear may occur. Therefore, the officer of the watch must coordinate the selection of the speed in ice with the engineering officer.

Ice must be entered at a right angle to its edge at the lowest possible speed, after first canceling the ship inertia. Movement should then continue, gradually increasing the speed of the screw so that a /101
safe speed of the ship is insured under the given circumstances.

The fact that ships navigating in ice answer the rudder poorly and have a greater tendency to yaw should be taken into account. Turns in ice should be executed with as smooth a change in heading as possible.

Navigation in ice is especially difficult and dangerous in poor visibility when tacking is difficult. Under such conditions navigation is possible only when one has complete confidence in the ability of the ship to pass through the entire ice region encountered.

4. Maneuvering the Ship When Recovering a Man Overboard

Success in maneuvering the ship when recovering a man overboard depends primarily on the efficient organization aboard ship as well as on fast, accurate and skillful actions on the part of the crew.

The first person to notice that a man has fallen overboard must, without waiting for orders, throw him a lifesaving piece of equipment, shout in a loud voice "Man overboard, starboard (port) side," and continue to watch the man overboard indicating his direction by pointing toward him. Each person hearing this report must repeat it in the direction of the bridge.

Having received the report "Man overboard, starboard (port) side," the officer of the watch shall:

- order to shift the rudder and operate the engine so as to prevent the man from getting under the ship and propellers;

- order lifesaving equipment to be thrown to him (a ring life buoy or a small raft);

- proceed to maneuver the ship according to the method selected by the Commanding Officer of the ship;

- when sailing in formation, give appropriate signals: hoist the "Ch" flag on the yardarm of the side from which the man has fallen;

sound a series of short blasts; transmit the "Ch" signal over ultrashort waves; and lower the colors to half mast. If navigating without lights at night, in peacetime, turn on the running lights and transmit the "Ch" signal by means of signal lights;

- announce over the ship's general announcing system "Man overboard, starboard (port) side" and organize a watch of the victim on the bridge, with a special lookout designated for this purpose; at night, turn on the searchlight to illuminate the site of the fall; /102

- make the lifeboat ready for hoisting out;

- upon completion of the ship's maneuver and in accordance with the Commanding Officer's decision as to the procedure for recovering the man overboard, lower the lifeboat or take the man directly aboard ship.

If the search and recovery of the man overboard is conducted with a lifeboat in daytime, the lifeboat is directed to the man by the lookout from the bridge and at night it is guided by the searchlight. The lifeboat moves toward the victim without the colors. Hoisting the colors on the lifeboat signifies that the man has been picked up, at which time the colors on the ship is hoisted all the way up and the signal "Ch" is lowered.

In heavy seas, because of the difficulty of hoisting the boats in and out, it is advisable to take the man directly aboard ship. In such a case, it is recommended to head into the wind when approaching the victim, stop the ship at a distance of 10-15 meters (the distance to the life buoy with the life line attached) and keep the wind and seas on the bow. Then take the victim on board.

The manner in which the "man overboard" maneuver is carried out depends on whether or not the man is visible in the water. If the man in the water can be seen from the bridge, the maneuver is conducted in the direction of the man overboard so that he can be approached and recovered by using one of the methods for taking him on board. In addition, the method of stopping the ship by going astern is widely used by large ships when sailing in narrow waters or moving at low speeds. After receiving a report about a man overboard the watch officer stops the engines, with the engine on the side from which the man fell stopped first. Then, he runs the engines full speed astern in order to prevent the ship from moving too far from the point where the man fell overboard. When the ship stops he orders the lifeboat lowered to rescue the man.

Should a man fall overboard either at night, in low visibility, or if the time of his fall is unknown, then the maneuver to search for the man is conducted--with a view toward getting back to the ship's original track--by one of the following methods:

<u>The half-turn method in which the ship comes to the reciprocal of the original course</u> (Fig. 5.1). The half-turn angle β is calculated from the formula: /103

$$\operatorname{tg} \beta = \frac{Д_{ц}}{kV_{к}t_{р}}, \tag{5.1}$$

where $Д_{ц}$ is the diameter of the turning circle, cable lengths;

k is the speed loss coefficient due to turning;

V_k is the speed of the ship, cable lengths/min;

t_p is the time required to put the rudder over, min.

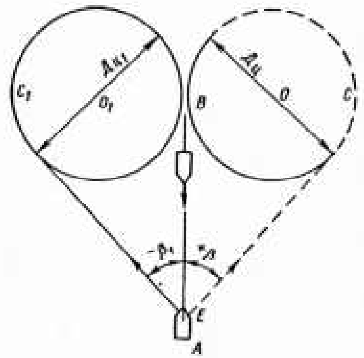


Fig. 5.1. Half-turn resulting in the reciprocal of the original heading

The turning angle can also be determined practically by maneuvering so as to get the ship to the reciprocal of her course. Maneuvering with this method does not depend on the time the man fell overboard and is, therefore, especially recommended in cases where a considerable period of time has elapsed since the fall.

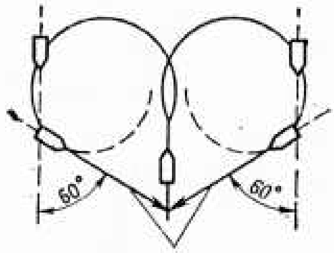
The calculated angles for various speeds of the ship should be tabulated and the table kept on the bridge.

<u>Method of turning through a calculated angle</u> (Fig. 5.2). The new heading for recovering a man is, in degrees: /104

$$K_{н} \approx K_{п} + 180^\circ \pm 60^\circ, \tag{5.2}$$

where K is the former heading in degrees.

The "plus" sign is used when turning to starboard and the "minus" sign, when turning to port. The effect of the ship speed on the magnitude of the angle is disregarded.



Heading to the point at which the man fell overboard

Fig. 5.2. Turning through a calculated angle

5. Ship Maneuvering When Transferring Cargoes Underway

The transfer of cargoes underway from supply ships to receiving ships is accomplished by three methods:

- the transverse method: to one or two ships;

- the columnar method: to one or two ships; and

- the combined method: to two or four ships.

The transverse method (the basic method) involves the following: both ships while sailing on parallel courses at the same speed and maintaining their stations, transfer the cargo laterally by using special rigs. The ships begin to maneuver after they come within visual range and after the heading, the speed and the sides to be used in transferring cargoes have been designated.

The supply ship maintains strictly the prescribed course and speed and the receiving ship maneuvers in order to maintain her station relative to the supply ship. The heading should be into the seas or at an acute angle to the seas. /105

The speed is usually set at 1.5 to 2 knots less than the full speed of the supply ship and, when transferring cargoes from one naval ship to another, the speed is set at the operational speed of the slower ship.

The distance between the sides of the supply ship and receiving ship

depends on speed:

- at a speed of 8-10 knots, the distance is 30-35 meters;

- at a speed of 12-14 knots, 40-50 meters; and

- at a speed of 16-18 knots, 50-70 meters.

After coming within 30-40 meters of the supply ship, the receiving ship gets on a parallel course and, after gradually adjusting her speed, moves abreast the supply ship.

By changing the heading in 1 to 3 degree steps and after setting up the rig and checking its operation, the receiving ship gradually increases the distance between the ships to that designated. On command from the man in charge, the speed is increased to that specified for the cargo transfer period. During the transfer the course and speed should, as a rule, be constant. If necessary, the course and speed are changed gradually without stopping the transfer. In doing so, shifting of the rudder and changing of the speed of rotation of the screws are done smoothly.

Changing the course of both ships is accomplished by making a series of turns, 5^{0} each. In doing so the following is observed:

- the rudder is set at an angle no greater than 5^{0};

- both ships change their respective courses on special signals;

- the receiving ship increases her speed by one knot with respect to the prescribed speed when on the outside of the turning circle and decreases the speed by one knot when on the inside;

- the supply ship strictly maintains the prescribed speed.

Changes in speed are conducted in steps, no greater than one knot at a time.

Upon completion of the transfer of cargoes and release of the equipment, the receiving ship executes a departure maneuver by changing her speed and course.

The columnar method involves the following: both ships steam in a column or in a line of bearing, maintain a given distance between them, and transfer cargoes by means of a special rig. The transfer of liquid cargoes by the columnar method can be carried out when the ships move as follows: /106

- the receiving ship moves in tow behind the supply ship;

- the receiving ship moves under her own power in a line of bearing; and

- the supply ship moves in tow behind the receiving ship.

For transferring liquid cargoes the columnar method is preferable. The transfer of dry cargoes by the columnar method is carried out only under tow.

Both ships begin to maneuver after coming within the visual range and receiving instructions for the heading, speed and the station in the formation. Depending on the situation, the speed is selected within 6-12 knots. In transferring cargoes without tow both ships sail in a line of bearing, maintaining a distance of 30 ± 20 meters between them and a distance of 100 ± 20 meters between the sternpost and stem along the heading.

In transferring cargoes under tow the distance between ships is 70-180 meters. The receiving ship approaches the supply ship on a parallel course from astern at a distance of 25-30 meters. After securing the tow line and gradually reducing speed the receiving ship smoothly takes a tow. During foul weather the receiving ship approaches the supply ship in a column to a distance which allows the hoisting aboard of buoys with the towline guides and hoses.

When taking on liquid cargoes without the tow the receiving ship, after receiving the hose line messenger, reduces her speed, gradually increases distance, and assumes her station in the formation, following which she takes a parallel course and adjusts her speed. If the receiving ship is to be the guide ship then it moves ahead of the supply ship and sets her speed based on the speed of the supply ship. The transfer of the tow line and messengers from the receiving ship to the supply ship can be carried out when the ship passes alongside the supply ship or when the receiving ship takes the position ahead of the supply ship.

Course changes of both ships performing the transfer of cargoes are carried out by making the successive 5° turns, with the rudder in the ship being towed set so that she moves along the outside edge of the /107
wake. The rudder on the towing ship is set an an angle no greater than 5°.

Upon completion of the transfer of cargoes and releasing the gear, the receiving ship reduces her speed (increases her speed if she is the guide ship), increases distance, and operates as prescribed.

In the combined method, the supply ship transfers cargoes to several ships by using special rigs and employing the transverse and columnar methods simultaneously. The ships perform maneuvering in accordance with the recommendation for the appropriate method of taking on cargoes.

Section 5.2. Anchoring a Ship or Mooring Her to a Buoy

1. Selecting an Anchorage Site

Providing for safe anchorage is the basic requirement an anchorage site must satisfy. In selecting the site one should take into account the size of the open water area; the depth; the type of the bottom; the direction and speed of the current; the availability of protection from wind, waves, and swell; the availability of navigational aids and natural landmarks for making the approach to the anchorage easier and for the timely detection of the beginning of the drift due to wind and current both day and night; the possibility for the ship to get underway quickly; the safety for entering and leaving the area in all situations; and the opportunity of setting up the defense.

The most suitable depths for anchorage range from 15 to 30 meters. Clay holds an anchor best, followed by silt, sand, and small rock. The holding power of an anchor is not very great on bottoms containing shells, pebbles, large rocks, and flagstones.

A water area may be considered acceptable for the anchorage of one ship and safe it a circle with the following radius can be inscribed within it:

$$R = L + l + \Delta l + f. \qquad (5.3)$$

where L is the length of the ship, m;

l is the scope of the anchor chain, m;

Δl is the scope of the anchor chain which can be payed out in cooler weather together with the depth of clear water one requires to have under these circumstances, m; /108

f is the greatest possible error of determining the position of the ship (of the location of the anchor), m.

Anchoring "on one's own" is done, as a rule, when a single ship is anchored in a roadstead. In this case the Commanding Officer selects the anchorage consistent with the mission of the ship and the situation.

Anchoring by "disposition" is the basic method for anchoring a force or group of ships because it is the best way to take into account the navigational safety of the anchorage and setting up the defense of the ship. Ships are anchored at the previously designated sites which can be given to them in the form of: a) the bearing and distance to the flagship or any other anchored ship; b) coordinates of the anchorage site; and c) the bearing and distance to some landmark. Mooring buoys, spar buoys, or dan buoys with the anchorage numbers are usually placed at the sites.

Anchoring by the "all together" method is the simultaneous anchorage of ships on signals from the flagship. The ships anchor in those positions which they occupied in the formation or order. This method is used by a well-coordinated formation of ships, since it requires especially efficient and well-coordinated actions on the part of their crews.

3. Anchoring a Ship

Maneuvering in order to anchor a ship at a given point is shown in Figs. 5.3 - 5.6. /109

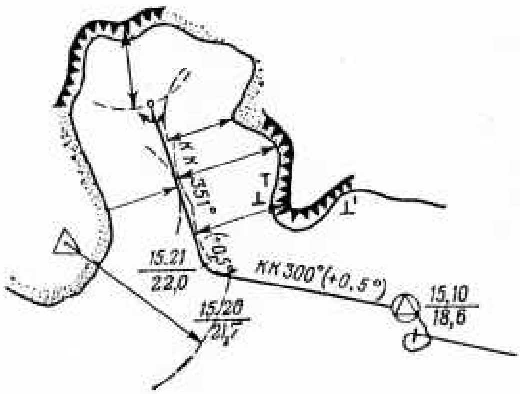


Fig. 5.3. Maneuvering a ship for anchoring with the use of radar

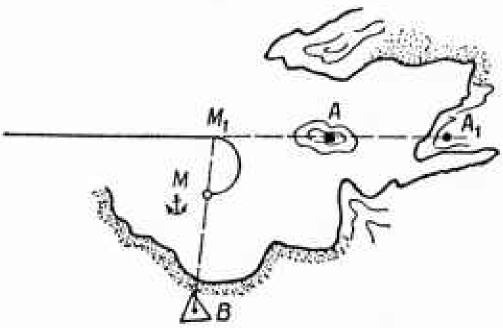


Fig. 5.4. Maneuvering a ship for anchoring with the use of an entrance range:

AA_1 - direction of the range;

M_1B - bearing at the beginning of the turn made for anchoring; and

M - place of anchorage

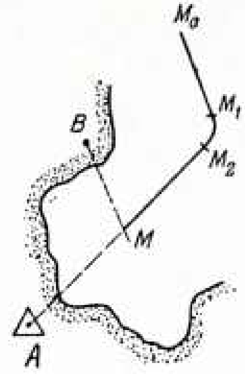


Fig. 5.5. Maneuvering a ship for anchoring by using two bearings;
M_0M_1 - approach course;
M_2MA - approach bearing; and
MB - anchorage bearing

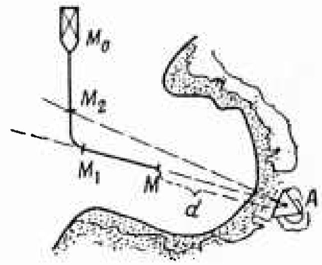


Fig. 5.6. Maneuvering a ship for anchoring by using a bearing and distance:
M_0M_1 - approach course;
M_1M - approach bearing; and
MA - distance to landmark at the time of anchoring

When the weather is favorable the following method of maneuvering a ship for anchoring is recommended: mark the place of anchorage and approach it at the lowest speed. Then, depending on inertia, move at a medium or low speed astern. As soon as the ship begins to move astern the engines must be stopped and at the moment the ship is almost completely stopped, drop anchor and pay out the anchor chain so that it lies evenly on the bottom. /110

From the beginning to the end of the maneuver the depth of the site must be repeatedly measured by means of an echo sounder and hand lead.

It is not permissible to drop anchor if the ship is moving rapidly

ahead or astern. With a strong current and (or) wind it is advisable to take a course on which the combined effect of the current and wind tends to move the ship astern.

The scope of the anchor chain which must be payed out under average weather conditions, and holding power of the bottom can be determined from Table 5.1.

Table 5.1

Recommended scope of anchor chain to be payed out when anchoring under average weather conditions

Depth of sea, m	Scope of anchor chain in hawse hole (in sea depths)
Shallow (up to 20)	4 (in harbors, from 6 to 10)
Average (21-50)	3
Deep (over 50)	1.5-2

For great depths it is recommended that the anchor chain be payed out almost up to the full depth of the site and only after this the stoppers be released.

In foul weather ships are usually anchored by means of two anchors. In this case, in order to avoid the anchor chain hitting the ship, the upwind anchor is dropped first. Then the ship is turned through an angle of not less than 30° in the direction away from the payed out anchor chain and is moved at the lowest speed ahead. After reaching, /111 roughly, the line of the first anchor the engines must be stopped, the ship must be moved astern and the second anchor dropped. Then, while moving back, its anchor chain is payed out as needed and the engines stopped. In order for the second anchor to take hold one should hold on to the chain until it is taut and then begin paying it out. Stoppers are applied when both anchor chains are aligned and have the same tension.

When securing with two anchors in foul weather a different method can also be used. While approaching the anchorage site the course of the ship should be perpendicular to the direction of the wind. Upon arrival at the point of anchorage, the engines must be stopped, the upwind anchor dropped while moving ahead by inertia and the anchor chain payed out. After the ship moves through the designated distance, her course is reversed, her engines stopped and, while she moves astern by inertia, her second anchor dropped. Positioned between the anchors,

the ship turns her bow against the wind and her anchor chains become taut and aligned so that the stoppers can now be applied.

4. Providing for Safety of Anchorage

The safety of a ship at anchor is insured by the reliability of the ground tackle, the holding power of the anchor and the degree to which the anchorage is sheltered from the wind and waves, as well as by the vigilance of the watch section and continuous weather observations. /112

With freshening weather the officer of the watch shall take all the following necessary measures to insure the safety of the anchorage:

- report freshening of the weather to the Commanding Officer of the ship;

- order that results of measurements of wind velocities be reported to him every hour or one-half hour (depending on the situation);

- inspect the ground tackle and check whether or not the anchor chain of the payed out anchor is too taut and jerking under tension;

- pay out the anchor chain if it jerks since otherwise the anchor could drag; the anchor chain should be payed out in small segments (8-10 meters) without giving it too much slack; each time it is payed out the stoppers should be set; the anchor chain should not be payed out when it is taut; it is better to wait until it slackens and begins to sag;

- clear away the second anchor;

- hoist the boats and launches or move them to a sheltered area;

- in heavy weather trice up the vertical ladders and raise the accommodation ladders;

- with the increasing wind and sea, secure for sea all objects which are on the main deck and which can move when the ship is rolling and pitching;

- periodically take bearings of landmarks or shore objects located as close to the beam as possible to detect the ship's drift in time; check periodically the readings obtained; drop a drag anchor from the forecastle to the bottom and, after slackening the line 15-20 meters, secure it to the deck; assign the forecastle watch to look after the drag anchor; should the anchor drag and the ship begin to drift, the line will tauten and its direction will indicate the direction of the leeway;

- with further freshening of the weather, drop the second anchor if the wind is inshore and if there is some danger that the ship will begin drifting toward the shore; the second anchor should be cast the moment the drift of the ship's bow away from the dropped anchor becomes maximal; following this slowly pay out both anchor chains and place the stoppers on them;

- when the freshening weather reaches storm proportions, with the permission of the Commanding Officer, make the ship ready to get underway immediately, issue an order to jack over the engines, turn on the electronic observation systems and set up an underway watch at all stations associated with shiphandling; if necessary, run the engines to support the anchors to keep the ship in place with the bow to the wind. /113

In order to provide for the defense of the ship the watch officer, in accordance with special instructions, must direct the watch of the Combat Information Center, set up a reliable surveillance of the surrounding area, maintain close communication with the flagship, know air and surface conditions, report them promptly to the Commanding Officer, and be able to use weapons and equipment to defend the ship.

When the ship is at anchor the watch officer must be on the main deck, primarily on the poop or at the accommodation ladders. In fresh weather when the ship is at anchor either under steam, when jacking over the main engines, or in other cases where personal observation of the surrounding area is required, the watch officer must be on the bridge (at the main control station) of the ship.

5. Mooring a Ship to a Buoy

Mooring a ship to a buoy has the following advantages over anchoring:

- accuracy of mooring;

- reliability;

- unmooring from a buoy requires less time than weighing anchor;

- less wear on the ship ground tackle; and

- the possibility for securing a large number of ships in a roadstead (with a changing wind a ship will turn in a circle with a radius only slightly exceeding her length and, when moored to two buoys, there is no turning at all).

Disadvantages of mooring to a buoy:

- mooring to a buoy requires somewhat more time than securing a ship by an anchor; and /114

- difficulty of maneuvering when mooring in fresh weather.

The speed and course of a ship when approaching a buoy must be set by taking into account the immediate situation and the force and direction of the wind and current. In calm weather with a light wind and no current the buoy can be approached on any course. If the wind or current is considerable it is recommended that approach headings be directed into the wind and current, if possible, so that the buoy is located on that side of the ship on which the anchor chain was made ready for mooring.

When approaching the buoy, steps should be taken for the ship not to pass the buoy or run into it. This is prevented by taking into account the ship's inertia, by approaching the buoy properly, and by stopping the ship in good time.

As the ship approaches the buoy the command "Lower the boat" is given. The boat is lowered into the water as the ship moving by inertia decelerates. After arriving at the buoy and when working on it, the boat with the oarsmen must be behind the buoy to avoid damage should the ship suddenly run into the buoy.

First a heaving line (a messenger) is cast from the ship to the buoy and then the wire rope runner. By pulling on the shackled fitter end of the wire rope with the windlass, the ship is heaved to the buoy. In daytime, after attaching the wire rope, the balls are lowered, the colors are shifted and the jack is hoisted; at night, the running lights are switched off and the anchor lights turned on.

Mooring to a buoy without using a boat is carried out as follows: after evaluating the situation at the mooring site and determining the force and direction of the wind and current, the Commanding Officer of the ship brings the bow of the ship all the way up to the buoy. At this moment, one of the sailors who is tied to a safety line, is lowered onto the buoy; he quickly passes the messenger through the buoy ring and secures it to the eye of the wire rope; the sailor is then lifted aboard. Following this, they proceed to shackle the anchor chain to the rope.

6. Mooring a Ship to Two Buoys

A ship is moored to two buoys when a roadstead or harbor is narrow and when one should prevent the ship from turning when the direction of the wind and current changes.

After mooring to the forward buoy the ship is towed to the second buoy or brought there with the aid of her own engines. A wire hawser with an eye is secured to the buoy ring with a shackle (or a slip rope is passed through) and then tightened by means of the capstan and secured to a bollard. The distance from the stern of the ship to the buoy must be no less than 15-20 meters. /115

Ships with small or medium displacements can be moored to buoys in pairs. The first ship maneuvers for mooring to two buoys, as described above, while the second moors alongside and, in addition, shackles the mooring lines to the forward and stern buoys.

7. Weighing Anchor (Unmooring from a Buoy)

The usual clearing of a ship for action and for sea is carried out on command "Clear the ship for action and for sea," while the emergency clearing is accomplished on command "General quarters. Emergency. Clear the ship for action and for sea." With these commands the crew take up their stations according to the station bill and take actions as specified in the appropriate instructions, station bill, and schedules.

Under ordinary clearing of a ship for action and for sea the watch officer assumes his watch one hour prior to weighing anchor (or unmooring from a buoy), if up to now only routine duties were performed aboard ship. In addition to his regular duties he shall:

- establish reliable communication with the flagship;

- take necessary precautionary measures with respect to boats, launches, and lines astern; set up an anchor chain lookout; and then, making sure the engine order telegraph is ready, authorize the watch engineer, with the knowledge of the Executive Officer, to jack over the engines;

- before unmooring the ship from the buoy, with permission from the Executive Officer, give the order to put the slip rope on the buoy and to unshackle the anchor chain. The anchor chain, heaved in by means of the capstan to the forecastle, is shackled to the anchor and the anchor is prepared for casting or stoppers are placed on the chain. When anchoring a ship in fair weather, take up the anchor chain to the number of meters specified by the Commanding Officer;

- if the ship is putting to sea alone, request permission for weighing the anchor or unmooring in good time; and if moored to a pier, call upon personnel from other ships to cast off the mooring lines; /116

- at night darken the ship.

Also, the watch officer must be certain that all engine and rudder control stations, sound and signal communication systems, radio electronic observation systems, running lights (at night) are ready and that the windings of the degaussing gear are energized.

Depending on the situation and the volume of work, the maneuver of weighing anchor (unmooring from a buoy) can be executed through general quarters, an all hands evolution, or by the anchor detail alone. In executing the maneuver through general quarters or the all hands evolution the watch officer turns over the watch to the Executive Officer of the ship and takes his station according to the bill.

Upon the Commanding Officer's order "Up anchor" the command "Heave and away" is given, whereupon they begin to heave the anchor chain. The lookout watching the position of the anchor chain and its markings, in response to queries from the bridge "How much is in the hawse?" and "How does the chain tend?", reports clearly: "So many meters" and "Anchor chain is taut (slack)," "It tends forward (back)"--and indicates the direction of the anchor chain by pointing. When the anchor breaks ground the lookout reports "Anchor is aweigh." This moment is easily determined by the accelerated rotation of the windlass as well as by the slackening and unwinding of the anchor chain. In addition, the "anchor's aweigh" position is found by comparing the depth of the anchorage site with the scope of the payed out anchor chain, determined from the marks.

In daytime, after receiving the report "Anchor's aweigh" the colors are shifted, the jack is lowered, and the balls are hoisted in place. At night, the running lights are turned on and the anchor light extinguished. From this moment the ship is considered to be underway.

The ship should not get underway immediately after receiving the report "Anchor's aweigh" since it may turn out that the anchor is not clear. In a strong wind or current the engines can be operated in order to maintain the ship in place. Only after receiving the report "Anchor is clear" and, when the situation permits, should the ship get underway. If a report "Anchor is not clear" is received, they begin to clear it immediately in accordance with the practice of seamanship.

In order to unmoor a ship from a buoy the command "Unshackle" is /117 given. Upon this command the anchor detail pays out the runner from the bollard and throws it overboard and the inboard end is quickly heaved in by the windlass. As soon as the runner of the rope is released from the buoy ring, the ship is considered to be unmoored.

If the ship is to pass through narrow waters, after weighing anchor or unmooring from a buoy, the anchor must be ready for immediate casting. Upon reaching open water the anchor is stored in place and secured for sea.

Section 5.3. Towing a Ship at Sea

1. General Considerations

In terms of pulling, three types of towing may be employed: towing in the wake, where the vessel in tow is behind the towing vessel; towing alongside, where the vessel in tow proceeds alongside the towing vessel (each of these types of towing can be carried out with the bow ahead or astern); towing by pushing, in which the pusher, with a special gear at the stem, resting against the stern of the ship in tow, moves it ahead. If the power of the towing vessel is inadequate, towing by two ships can be used.

If the hull of the vessel to be towed is sound or if the stern is damaged, towing in the wake with the bow ahead is recommended. Towing in the wake with the stern ahead is used when the vessel to be towed has a hole underwater in the forebody and it is feared that the bulkheads of her flooded compartments would not withstand the pressure of the water while in tow with the bow ahead.

Alongside towing is convenient and advantageous in those cases where the hull of the vessel in tow has holes or other damages. However, this type of towing is done only on short runs and in sea states of not greater than 3.

Towing by pushing is used, as a rule, on rivers.

Flexible wire ropes are used primarily as towing lines for astern /118
towing of warships. When towing in fresh weather it is recommended that wire ropes be made heavier artificially by using a combination towing line consisting of a wire rope and anchor chain connected by a trolley shackle. In this case the wire rope is usually passed from the towing vessel and the anchor chain is passed from the vessel in tow, after first being unshackled from the anchor. From the weight of the anchor chain the towing line sags, cushioning the jerks and impacts which inevitably arise when towing in fresh weather. It is recommended that the scope of the towing line be adjusted so that while towing in a seaway both ships rise on the wave at the same time, i.e., the scope of the towing line must be a multiple of the length of the sea wave (Fig. 5.7).

In the general case it is recommended that the scope of the towing line be selected according to the displacement of the ship in tow and according to the sea state (Table 5.2).

In towing, the speed of the ships depends on the strength of the towing line and towing gear, the size and condition of the ship in tow, and on the force of the wind and the sea state.

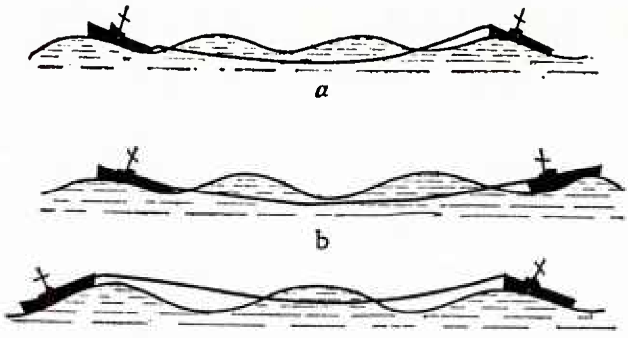


Fig. 5.7. Tension on the towing line as a function of the position of the vessels on a wave:

a - proper scope of towing line, multiple of the wavelength;

b, c - improper scope of towing line, equal to an integral number of wavelengths plus one-half of wavelength

Table 5.2

Scope of the towing wire rope for towing ships as a function of ship displacement and sea states

Displacement of ship in tow, t	Scope of towing line in a sea state, m	
	Up to 3	Up to 6
450	170 - 180	300 - 350
800	200 - 220	400 - 450
1700	260 - 270	500 - 550
4500 and higher	300 and higher	650 and higher

In towing, the magnitudes of the thrust and torque of the electromechanical system increase and, in the event they exceed the established limits, the electromechanical system can be damaged. In order to avoid this, the watch officer must coordinate setting of the tow speed with the officer in charge of the engineering department. /119

The towing line tension and speed of the ships are calculated from the empirical formulas or determined from the previously calculated tow

graphs. The total tension in a towing line without taking into account the effect of the seaway is, in tons:

$$R \quad R_1 + R_2 + R_3, \tag{5.4}$$

where R_1 is the tension in the towing line without taking the wind into account and with freely rotating propellers on the ship in tow, in tons;

R_2 is the resistance produced by the stopped propellers, in tons;

R_3 is the air drag produced by the ship in tow, in tons.

The tension in the towing line in tons is:

$$R_1 = \frac{v^2}{k} S, \tag{5.5}$$

where v is the towing speed, knots;

S is the underwater midsection area of the ship in tow, m^2;

k is an empirical coefficient which for light cruisers is 350-400 and for destroyers, 200-250.

The resistance of a single stopped propeller in tons is: /120

$$r = 2.24\ D^2 v^2, \tag{5.6}$$

where D is the diameter of the propeller, m;

v is the towing speed, knots.

If the ship in tow has several propellers, then the resistance increases in proportion to their number.

The air drag of the ship in tons is:

$$R_3 = k_1 F v^2, \tag{5.7}$$

where $k_1 = 0.122$ is the air drag coefficient;

F is the area of the projection of the above-water part of the ship on the midsection plane, m^2;

v is the actual velocity of the head wind plus the towing speed, m/sec.

It is recommended that tow graphs showing the tension in standard towing lines as a function of speed of towing be calculated in advance for each ship and various conditions (Fig. 5.8).

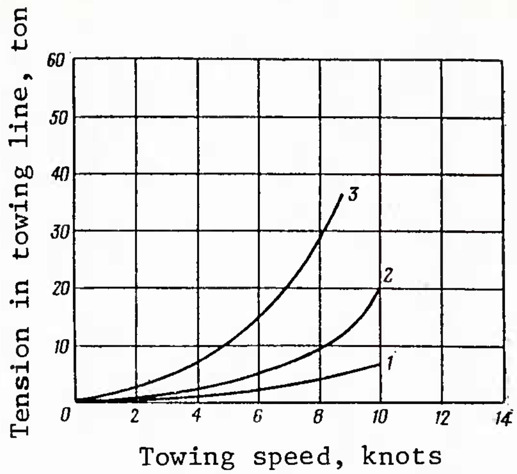


Fig. 5.8. Tow graph. Propellers are stopped:

1 - frigate; 2 - destroyer; 3 - cruiser

Data for constructing graphs can be obtained from calculations by means of formulas or experimentally. In the latter case the ship is towed at various speeds and the tension in the towing line is measured for each of them by means of a dynamometer. /121

2. Towing a Submarine

Submarines are usually towed in the wake. Towing alongside is permitted only in exceptional cases in fair weather.

On submarines towing lines are secured to the hoisting rings or to the sail. Their scope ordinarily does not exceed 100-150 meters. The towing speed is as follows: in a seaway, no greater than 7 knots; and in fair weather, depending on the situation.

3. Towing Practice Targets

The towing of practice targets and development of speed should be smooth in the beginning just as it is done when towing ships. In view of the fact that in towing targets the scope of the towing line is normally 600-800 meters or longer, the line sags, thereby insuring the towing reliability.

Practice targets exhibit limited maneuverability. Therefore, when towing in fresh weather, they should be maneuvered carefully and their headings with respect to the direction of the sea properly selected. In a sea state greater than 5 one should avoid headings into the sea or with the sea since the hull of the target can experience stresses tending to break it in half. The headings that are considered the most

favorable for towing targets are those which form angles of 30 to 40° with the direction of the sea.

4. Recommendations to the Watch Officer on Towing

Since the towing line experiences maximum load the moment the vessel in tow begins moving, speed must be developed gradually in order to /122 avoid breaking of the towing line. The procedure for developing speed is as follows: start with the steerageway for a short period of time and as the towing line becomes taut stop the engines. As soon as the towing line begins to sag, start with the steerageway for a short period of time again. By maneuvering in this manner one should increase the speed smoothly until steerageway is achieved. Towing should be continued initially at steerageway and then the towing speed should be gradually increased up to the required speed.

In turning, the towing ship should decrease her speed and place the rudder at a small angle (within 5-8°). For the ship in tow, especially when turning through large angles, the rudder should be set so that the ship would proceed along the outer edge of the wake.

If the towing line breaks, the engine must be stopped immediately to prevent the remaining towing line from winding around the propellers.

In order not to veer away from the required course in the wake when the rudder of the ship in tow is jammed at an angle greater than 10°, one should increase the speed of rotation of the towing ship screw located on the side opposite to that in the directions of which the rudder is jammed. In towing alongside, the screw on the side in the direction of which the rudder is jammed should be rotating at a greater speed.

When towing in a seaway the tension in the towing line and the behavior of ships should be carefully watched, and the towing line payed out or taken in so that it would not experience abrupt jerking. Experience shows that towing becomes reliable when the towing line scope and sag are such that the sag does not come out of the water regardless of the jerking force strength.

The magnitude of the required towing line sag in meters is:

$$\gamma = \frac{Pl}{2000R}, \tag{5.8}$$

Where P is the weight of one-half the length of the line, tons;

l is one-half the length of the payed out line, m; and

R is the resistance of the ship in tow (pull on the towing hook), tons.

If the scope of the towing line is too short and there is no way to increase it, and if the line begins to jerk and become taut in fresh weather, the towing speed must be decreased immediately. /123

The watch posted at the towing gear in the stern of the ship must be periodically checked so as to be ready to cast off the towing line immediately and maneuver the ship freely, should it become necessary.

Section 5.4. Ships Sailing in Company

1. General Considerations and Definitions

Sailing in company involves two or more ships at sea under a single command, steaming in formation or order.

Formation is the simplest order, in which ships are arranged along one (simple formation) or several (multiple line formation) straight lines. A formation is described by its elements (Fig. 5.9).

Line of formation is the line connecting identical points on ships in formation; its direction is counted from the guide.

Bearing of formation is the angle between the true meridian and the direction of the line of formation, measured clockwise.

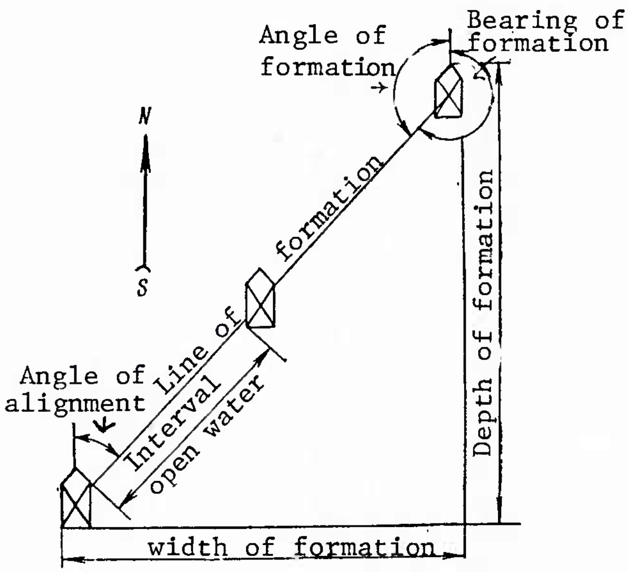


Fig. 5.9. Elements of a formation

Angle of formation is the angle between the center plane of the guide and the line of the formation.

Angle of alignment is the angle between the center plane of the ship and the direction to the guide.

Depth of formation is the distance from the stem of the leading ship to the sternpost of the rear ship in the direction of the formation's movement.

Width of formation is the distance between the outer sides of the rear ships in the direction perpendicular to the direction of movement of the formation.

Distance between ships in the formation is the interval of the open water between adjacent ships.

Simple formations:

- column is a formation in which the line of the formation coincides with its course (the ships move in a single column);

- line abreast is a formation in which the line of formation is perpendicular to the direction of movement; /124

- line of bearing is a formation in which the angle of the formation is not equal to 90° (line abreast formation) or 180° (column);

- bow-and-quarter line is a special case of the line of bearing in which the angle of alignment is equal to 45° (135°).

Multiple-line formations:

- wedge formation is a formation in which the ships are arranged along the sides of an angle with the guide at the vertex;

- multiple line-abreast formation is a formation in which the ships proceed in several parallel lines each of which constitutes a line-abreast formation.

The formation of a naval force (of a group of ships) is a strictly established, in terms of the direction and distance, disposition of ships maneuvering together in battle (battle formation) or cruising at sea (cruising order). /125

A circular formation is a formation in which the screening ships are arranged in concentric circles. Depending on the arrangement relative to the ships being protected, the screening may be circular or in the form of a curtain in which the screening ships are stationed along

a section of the circle, where the threat of the enemy attack is the greatest.

The center of a circular formation is the center of the concentric circles along which both the ships being protected and the screening ships are arranged.

The guide of a force in a formation (order) is the flagship or the ship designated by the Commander of the force. In a column the guide is always the leading ship of the column.

In the line abreast, bearing, and wedge formations the flagship is the guide.

It is customary to communicate to the screening ships their position in the formation by indicating the distance from the guide (from the center of the formation) to them in cable lengths and their course angle.

When sailing in formations or orders, apart from plotting the course of own ship, the course of the flagship must also be plotted by each ship. A diagram of the formation (order) must also be available on tracing paper in the scale of the chart, so that one would, by placing it over the chart, be able to plot the position of any ship in the formation (order) at any time. Before turning one's own ship one should make sure, either visually or by using electronic equipment, that there are no ships or vessels dangerously close to the ship especially in the area to which the turn will be made.

In executing all turns in a formation (order) the rudder must be set at an angle corresponding to the standard turning circle diameter established for the given force).

2. Methods of Changing Course in Formations

Turning in succession is used only in a column formation. The leading ship sets the rudder at a specified angle. When they arrive at the point where the leading ship made her turn, the remaining ships begin to turn by slightly increasing or decreasing the rudder angle while keeping the stem at the outer edge of the wake of the ship ahead. /126

The time interval t_i between the start of a turn by the leading ship and by the i-th ship is, in seconds:

$$t_i = \frac{d_{1i}}{V}, \tag{5.9}$$

where d_{1i} is the distance between the leading and i-th ship at the time

the leading ship begins to turn, m;

V is the speed of the formation, m/sec.

The formation's turning time is, in seconds:

$$t = \frac{L}{V} + t_{\alpha}, \tag{5.10}$$

where L is the depth of the formation, m;

t_{α} is the time required for turning at angle α, sec.

The simultaneous turn. On signal from the flagship all ships begin to turn simultaneously. The turning time is the time required to turn onto a new course.

Turning by the wheeling method. The diagram shown in Fig. 5.10 demonstrates the execution of this turn. The turning line A_0F is drawn (from the position of the end ship located on the inside of the turn) at an angle--with respect to the line perpendicular to the old course--equal to one-half the turn angle ($\alpha/2$).

When the execution signal is given the ships located on the outside of the turn (counting from the center of the formation) increase their speed to flank speed while the ships on the inside of the turn reduce their speed to low speed, with the center ship moving without making any changes.

Upon arrival at the turning line, the ships turn independently onto the new course. After taking their stations in the formation all the ships independently proceed at full speed. Changing the course by the wheeling method is practical when turning at angles no greater than 60°.

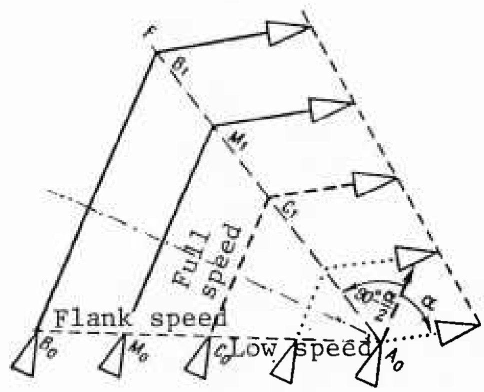


Fig. 5.10. Turning by the wheeling method

The time required for turning a formation onto a new course is, in seconds:

$$t_{пов} = \frac{L}{V_{спх}} + \frac{2H \sin\frac{\alpha}{2}}{V_{спх} - V_{мх}} + t_{\alpha}, \qquad (5.11)$$

where L is the depth of the formation, m;

H is the width of the formation, m; /128

α is the turning angle, degrees;

$V_{спх}$ and V_{Mx} are flank speed and low speed in m/sec, respectively.

Turning by the method of two half-turns (Fig. 5.11). Upon arrival at the line of the first half-turn, each ship takes an intermediate course by turning at one-half the angle of the new course. On the intermediate course, the ships located on the outside of the turn (counting from the center of the formation) continue to move at full speed up to the line C_1B_2. At this point they independently reduce their speed to medium speed. The ships on the inside of the turn, while making the

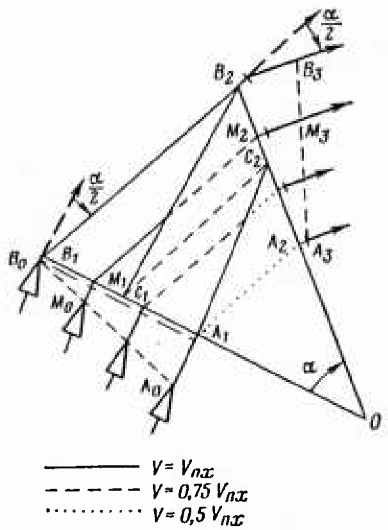


Fig. 5.11. Turning by the method of two half-turns

turn, move at medium speed and proceed up to the line A_1C_2. At this point they reduce their speed to low speed. The outermost ship and the innermost ship do not change their speed on intermediate courses so that the former continues to proceed at full speed and the latter at low speed. With an odd number of ships in the formation the center ship

proceeds at medium speed. Upon arrival at the second half-turn line OB_2, each ship turns once again at one-half the new course angle and increases the speed to full speed.

The search turn (Fig. 5.12). This turn is executed without changing speed. With the execution signal, the outermost ship (on the outside of the turn) immediately turns onto the new course. The rest of the ships continue on the old course until they arrive at the turning line which is the bisector of the turning angle α drawn from the turning point of the first vessel to begin turning. Upon arrival at the turning line each ship turns onto the new course. /129

In turning onto the new course the total turning time for the line abreast formation is, in seconds:

$$t_{\text{поп}} = \frac{H \operatorname{ctg} \frac{\alpha}{2}}{V_{\text{пх}}} + t_{\alpha}. \qquad (5.12)$$

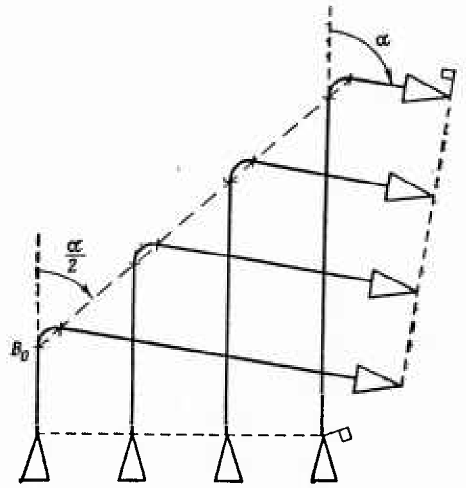


Fig. 5.12. The search turn

3. Methods of Changing Course in Formations

The basic method for changing course in formations with circular screening is the "simultaneous" turn method while in formations with curtain screening--the wheeling and breakoff methods.

The simultaneous method of turning (Fig. 5.13). All ships begin to turn simultaneously on signal from the flagship. Turning can be made at any angle. However, when sailing in a closed formation, turning at an angle of more than 90°, when using the simultaneous method, is not recommended. The formation turning time is equal to the turning time of a single ship.

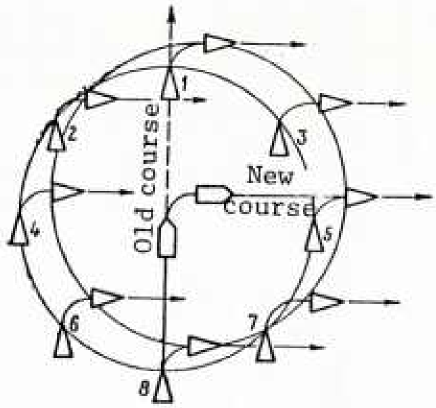


Fig. 5.13. Changing the course of a formation by the "simultaneous" method

The wheeling method of turning (Fig. 5.14). Each ship in the formation changes course on the same line, called the turning line. The latter is drawn through the turning point Γ_0 of the leading ship at an angle (to the line perpendicular to the old course) equal to one-half the new course angle ($\alpha/2$). The wheeling method is most suitable for making course changes of up to 60°.

The procedure for executing turns by the wheeling method:

- on signal from the flagship the leading ship turns onto a new course without changing speed;

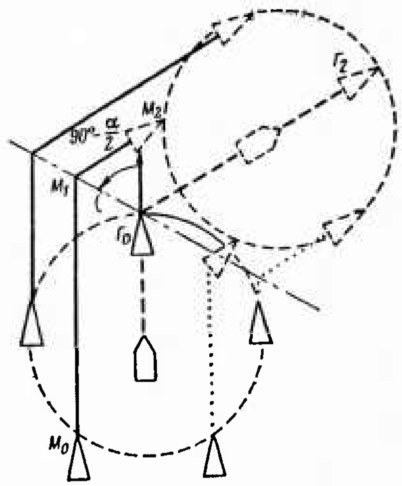


Fig. 5.14. Turning by the wheeling method

- the screening ships located on the outside of the turn increase their speed to flank speed while those located on the inside of the turn decrease their speed to low speed and continue following their original course up to the turning line; /131

- upon arrival at the turning line each ship steers the given course independently and, while keeping her station in the formation, proceeds at full speed;

- the escorted ship, upon reaching the turning point of the leading ship in the screen, steers the new course and follows in the wake of the leading ship without changing speed.

The breakoff method of turning (Fig. 5.15). In order to change the direction of movement of a formation the screening ships are divided into two groups when making the turn. After completion of the turn, they change their tactical numbers and, hence, their stations with respect to the guide. The breakoff occurs at the time the turn begins at the breakoff line, which is drawn through the center of the formation. As a rule, the breakoff line coincides with the new course of the formation. However, in certain cases it can run at an angle to the new course.

With large turning angles (greater than 60°), turning of a formation by the breakoff method permits making course changes in the shortest time possible.

Making changes in course by using the breakoff method is not recommended when sailing at night or when visibility is poor.

The procedure for changing course by the breakoff method:

- with a signal from the flagship, all the screening ships determine their new stations and courses to be followed in reaching them;

- when the execute signal is given the screening ships steer the courses determined simultaneously and execute speed maneuvers so that by the time the guide completes her turn onto the new course they take their new stations;

- the main body of ships follow their original course without changing speed and, after traveling a distance equal to that between the nearest screening ship and the center of the formation, proceed onto the new course;

- after taking their stations with respect to the guide on the new course, the screening ships steer the new course independently and keep their stations in the formation.

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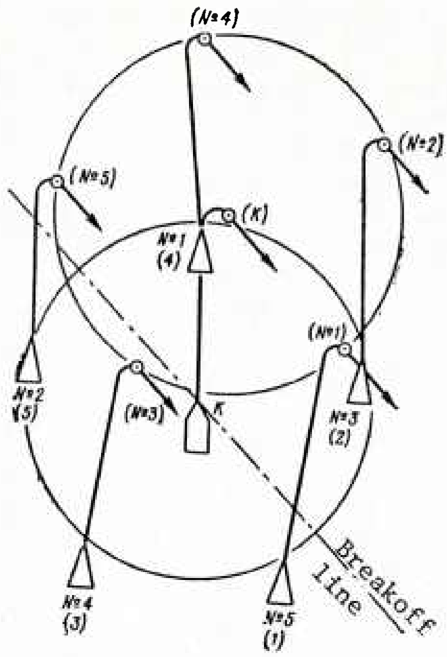


Fig. 5.15. Turning by the breakoff method

4. Steaming in Company at Night (in low visibility)

As nightfall (low visibility) approaches all ships must keep their stations in the formation and follow their original course and speed. If there were no special instructions, the ships either switch the prescribed lights on or are darkened following the lead of the flagship. Any ship sighting unauthorized lights on another ship must immediately inform that ship.

To insure navigational safety in low visibility (in fog, snowfall, /133
or rain) it is necessary:

- to step up combat readiness;

- to prepare the electronic lookout systems for immediate operation and carry out continuous observations, unless directed otherwise;

- to increase visual lookout;

- to determine and verify, as frequently as possible, own ship position, especially when sailing in a region with navigational hazards;

- to ready the ship and her systems for carrying out damage control operations;

- to give appropriate sound signals (in peacetime).

5. Steering Variable Courses

Single ships or ship formations follow variable courses when navigating in areas where there is a threat of attack by enemy submarines. Zigzagging and sinuating are the basic methods used in changing courses sharply.

The zigzag is a method of tactical deception performed by steering the ship along a variable course in order to make it more difficult for the enemy to determine ship motion characteristics and to use his weapons.

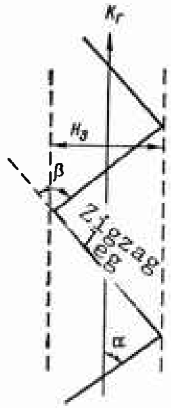


Fig. 5.16. Zigzagging

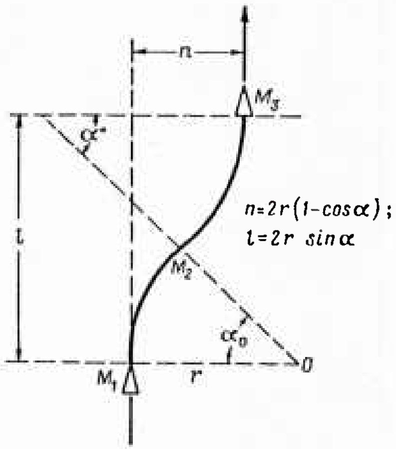


Fig. 5.17. Sinuating

Components of the zigzag maneuver:

- base course K; it is the line about which the zigzag is performed (Fig. 5.16);

- base route S--the useful distance which the ship travels along the base course in a given time interval;

- base speed V_r--the average speed along the base course;

- zigzag leg--the course between two consecutive turns;

- turning angle β--the angle between two consecutive zigzag legs;

- variation angle α--the angle between a zigzag leg and the base course;

- width of the zigzag H_3--the distance, along the perpendicular to the base course, between the outermost points on the zigzag. /134

Depending on the variation angle, the length of time the ship stays on the zigzag leg, the zigzag position with respect to the base course, and the way zigzags are executed, one classified zigzag maneuvers as follows:

- regular, i.e., zigzags in which the variation angle and the length of time the ship stays on zigzag legs are constant;

- irregular, i.e., zigzags in which zigzag legs or the length of time the ship stays on them are repeated only after several course changes or not repeated at all;

- simple, i.e., zigzags in which zigzag legs are repeated every other time;

- complex, i.e., zigzags in which zigzag legs are repeated every several turns or not repeated at all.

Zigzag maneuvers can be executed on signals from the flagship or at the prescribed time (using the zigzag type assigned in advance by the flagship). In the latter case, in handling the ship, it is practical to use the previously prepared tables containing individual zigzag legs (true and compass-type), time for making turns, angles, and the directions of turns.

Sinuating maneuvers consist of two consecutive turns which are /135
executed in different directions one right after the other (Fig. 5.17). After executing these maneuvers the ship continues on a course parallel to the previous course.

The sinuating maneuver is used to avoid floating mines, aerial bombs, etc., and can be executed in either direction from the base course and at different angles.

6. Some Recommendations to the Watch Officers on Ships Sailing in Company

When relieving the watch, the officer of the watch should make sure that documents regulating the sailing of ships in company are on the bridge.

When reading the signal from the flagship concerning maneuvering, the officer of the watch--even though fully confident of his knowledge of regulations on the execution of the maneuvers--must familiarize himself with them once again (if the time and situation permit) in order to perform the maneuver correctly and efficiently.

In order to insure safety when navigating in company the officer of

the watch must effectively utilize the electronic and visual lookout equipment, taking into account the situation in the area and the nature of ship's mission.

The officer of the watch must see to it that the ship keeps her station exactly in the formation or order. The station is kept according to the bearing and range to the guide. The bearing is taken on the center of the bridge of the guide. In the column and line-of-bearing formation, the range is the interval measured to the stern of the ship ahead while in the line abreast formation, the range is the interval measured to the line passing through the bridge of the ship ahead athwartship. When using radar the range is the interval of open water between the ships.

The engine order telegraph should be used for station keeping in the formation only in exceptional cases. It is recommended that all orders concerning changes in speed be made by conventional signals (such as bells, for example).

When a ship moves out of a formation or order, the watch officer must immediately notify the flagship as well as the ships astern with an appropriate signal, indicating the direction of the turn, and then /137 report to the Commander of the formation the reason for sheering off and the nature of any damage. The ship moving out of a formation (order) must take all measures to prevent collision and must not interfere with the movement of the formation.

By utilizing special signals displayed by means of balls to indicate changes in speed in the formation, the officer of the watch shall (Fig. 5.18):

- when increasing speed, first order the change in engine speed and then haul down the balls slightly;

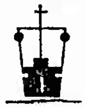
- when reducing speed, first hoist the balls and then order the change in engine speed.

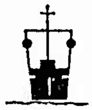
Fifteen minutes before sundown the watch officer must issue an order to check the searchlights, running lights, and the night signal generating equipment.

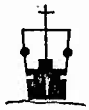
Section 5.5. Controlling the Operation of the Propulsion Power Plant

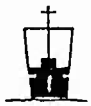
The system which propels the ship is called the propulsion power plant. A steam power plant is a propulsion system which uses steam boilers operating on conventional fuels and steam turbines as the main engines; a diesel power plant is a propulsion system which uses internal combustion engines; a gas turbine power plant is a propulsion system

Balls hoisted to the yardarm  Engines stopped

Balls hauled down 1-2 diameters from the yardarm  Engines operating at steerageway

Balls hoisted to 3/4 the height between the bridge and yard  Engines operating at low speed

Balls hoisted to 1/2 the height between the bridge and yard  Engines operating at medium speed

Balls hauled down  Engine operating at full speed

Each ship in the formation--should the situation require them to request the rest of the ships to go full speed astern, stop and keep their stations dead in the water--should hoist a cone with the vertex pointing upward while giving a series of short siren blasts in order to attract attention.

Fig. 5.18. Special speed signals

using gas turbines as the main engines; the steam, diesel and gas-turbine power plants may employ electric motors as the prime movers; a nuclear power plant is a propulsion system using atomic reactors. The recommendations given below are applicable to steam, diesel and gas-turbine power plants.

1. Use of the Equipment for Controlling the Operation of Power Plants (Main Engines)

To control the operation of the main engines aboard ship use is made of the main or emergency engine order telegraphs, the engine room bell system, the internal communication system, and the ship telephone system. At the present time, a number of ships use remote systems for controlling /138
the operation of power plants from the bridge and other control stations.

All main engine control equipment should be carefully checked and adjusted before a ship can go to sea. The officer of the watch must obtain a report from the engineering watch officer concerning the operational readiness of the main engine control equipment.

Immediately before a ship weighs anchor (casts off) the Commanding Officer of the ship (or the officer of the watch) checks the operation of the engine order telegraph by placing the telegraph lever in the "Full speed ahead--Stop" and the "Full speed astern--Stop" positions, after which he gives the following order to the engineering department control station: "The designated speed is so many knots; execute the orders of the standard engine order telegraph." He then moves the engine telegraph levers to the "Stand-by" position. When altering a previously designated speed underway, the Commanding Officer of the ship (or the officer of the watch) orders the engineering watch officer "To set the prescribed speed at so many knots." The time of switching to the newly prescribed speed is when the pointer of the engine telegraph is moved through the "Stop" to its original position.

In controlling the engines the officer of the watch must be strictly guided by instructions on the use of propulsion systems. The order for a temporary change in speed without changing the designated speed is given by the Commanding Officer of the ship (or the officer of the watch) by telephone "Maintain so many RPMs," without resorting to the use of the engine order telegraph.

In using the engine order telegraph one should observe the following regulations:

-- in order to proceed at a given speed, set the pointer of the engine order telegraph at the appropriate position on the dial and use the repeatback pointer to check whether or not the signal has been correctly understood in the engine room;

- by watching the tachometer pointer, make sure that the telegraph order to the engine has been executed in complete agreement with the table showing the relationship between the ship's speed and the speed of the screw. If there is no agreement find out the reason and take necessary measures immediately;

- in case of misalignment in the engine order telegraph, switch to the emergency engine control system (such as the emergency engine order telegraph, bells, telephone, or the internal communication system). After eliminating the malfunction switch the control of the engines to the standard engine order telegraph and issue an order "Execute orders of the standard engine order telegraph." For issuing the order use the telephone or some other means of communication. Switching to the emergency engine control system is done without issuing any orders. /139

For convenience in controlling the engines and using the engine order telegraph the following standard (prescribed) speeds have been established:

- steerageway--the lowest speed at which a ship can be steered;

- low speed--one-half of standard (prescribed) speed;

- medium speed--three-fourth of a standard (prescribed) speed;

- full speed--standard (prescribed) speed;

- flank speed--a speed 4 knots kigher than standard (prescribed) speed.

After the command "Flank speed" is repeated twice over the engine orger telegraph, the engineering watch officer must take all measures to develop maximum speed.

The bell system is used to transmit orders as follows:

- to increase speed by 10 rpm--two long rings;

- to decrease speed by 10 rpm--one long ring.

The following conventional signals are transmitted using the bell system:

a) headway:

- steerageway--one long, one short (- .);

- low speed--one long, two short (- ..);

- medium speed--one long, three short (- ...);

- full speed--one long, four short (- ....).

b) sternway:

- steerageway--one short, one long (. -);

- low speed--two short, one long (.. -);

- medium speed--three short, one long (... -);

- full speed--four short, one long (.... -).

c) stopping the engine--one short, one long (. -), transmitted four times.

2. Some Recommendations for Using the Engines /140

With the signal "Clear the ship for action and for sea" personnel of the engineering department clear for action and get underway by order of the engineering department head who determines what machinery will be operating during the cruise and what speed, prescribed by the Commanding Officer of the ship, should be. When the report is received that the engineering department is ready for action and for sea, the required systems are brought into operation in accordance with instructions on the operation of the main engines.

Testing the propeller by rotating it in the course of clearing the ship for action and for sea can be carried out only with permission of the watch officer. Also, if the ship is moored by the stern, testing of the propeller is done by rotating it only ahead. During testing, all orders transmitted to the engine rooms from the control center via the engine order telegraph or communication systems are executed only after the watch officer gives the command "Execute the orders of the engine order telegraph." This command is given after the head of the engineering department reports to the Commanding Officer (or the Executive Officer) that the engineering department is ready for action and for sea.

In case it is necessary to change the prescribed speed, requiring an increase in the number of operating boilers, the Commanding Officer of the ship (or the officer of the watch) must notify the engineering officer about the change in advance.

To insure stable operation of the power plant at sea, frequent changes in the prescribed speed are undesirable. When navigating in narrow channels or when moored or anchored, frequent speed reversals are prohibited, unless they are absolutely necessary.

After steaming sternway for extended periods of time the ship using a steam-turbine power plant should switch from sternway to headway only in accordance with instructions on the operation of propulsion systems.

If permission is requested from the engine room by telegraph to stop one engine in order to reduce speed, or if they stop one engine on their own, the Commanding Officer (or the watch officer), in order to prevent accidents, should give the order "Stop" to the second engine as well, as long as the stopping of the second engine does not jeopardize the ship's safety. If it is impossible to stop the second engine, its speed must be reduced to the minimum.

The officer of the watch must alert the head of the engineering department one-half hour before the arrival of the ship at an anchorage or before passing through a narrow channel. /141

If, after stopping the main engines, it is not anticipated that the ship will be ordered underway immediately, the command "Engines not needed. Condition of readiness to get underway is such and such" must be transmitted to the control station of the engineering department. After receiving this command, orders to get underway, which are transmitted by the engine order telegraph, should not be executed.

CHAPTER 6

INTERNATIONAL REGULATIONS FOR PREVENTING COLLISIONS AT SEA, 1972 (IRPCS-72) /142

Part A - General

Rule 1. Application

(a) These rules* shall apply to all vessels upon the high seas and in all waters connected therewith navigable by seagoing vessels.

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* IRPCS-72 become effective after ratification, but no earlier than 1 January 1972, and replace RPCS-60.

(b) Nothing in these Rules shall interfere with the operation of special rules made by an appropriate authority for roadsteads, harbors, rivers, lakes or inland waterways connected with the high seas and navigable by seagoing vessels. Such special rules shall conform, as closely as possible, to these Rules.

(c) Nothing in these Rules shall interfere with the operation of any special rules made by the Government of any State with respect to additional station or signal lights or whistle signals for ships of war and vessels proceeding under convoy, or with respect to additional station or signal lights for fishing vessels engaged in fishing as a fleet. These additional station or signal lights or whistle signals shall, so far as possible, be such that they cannot be mistaken for any light or signal authorized elsewhere under these Rules.

(d) Traffic separation schemes may be adopted by the Organization for the purpose of these Rules. /143

(e) Whenever the Government concerned shall have determined that a vessel of special construction or purpose cannot comply fully with the provisions of any of these Rules with respect to the number, position, range or arc of visibility of lights or shapes, as well as to the disposition and characteristics of sound-signalling appliances, without interfering with the special function of the vessel, such vessel shall comply with such other provisions in regard to the number, position, range or arc of visibility of lights or shapes, as well as to the disposition and characteristics of sound-signalling appliances, as her Government shall have determined to be the closest possible compliance with these Rules in respect to that vessel.

Rule 2. Responsibility

(a) Nothing in these Rules shall exonerate any vessel, or the owner, master or crew thereof, from the consequences of any neglect to comply with these Rules or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

(b) In construing and complying with these Rules due regard shall be had to all dangers of navigation and collision and to any special circumstances, including the limitations of the vessels involved, which may make a departure from these Rules necessary to avoid immediate danger.

Rule 3. General definitions

For the purpose of these Rules, except where the context otherwise requires:

(a) The word "vessel" includes every description of water craft, including nondisplacement craft and seaplanes, used or capable of being used as a means of transportation on water.

(b) The term "power-driven vessel" means any vessel propelled by machinery.

(c) The term "sailing vessel" means any vessel under sail provided /144
that propelling machinery, if fitted, is not used.

(d) The term "vessel engaged in fishing" means any vessel fishing with nets, lines, trawls or other fishing apparatus which restrict maneuverability, but does not include a vessel fishing with trolling lines or other fishing apparatus which do not restrict maneuverability.

(e) The word "seaplane" includes any aircraft designed to maneuver on the water.

(f) The term "vessel not under command" means a vessel which through some exceptional circumstance is unable to maneuver as required by these Rules and is therefore unable to keep out of the way of another vessel.

(g) The term "vessel restricted in her ability to maneuver" means a vessel which from the nature of her work is restricted in her ability to maneuver as required by these Rules and is therefore unable to keep out of the way of another vessel.

The following vessels shall be regarded as vessels restricted in their ability to maneuver:

(i) a vessel engaged in laying, servicing or picking up a navigation mark, submarine cable or pipeline;

(ii) a vessel engaged in dredging, surveying or underwater operations;

(iii) a vessel engaged in replenishment or transferring persons, provisions or cargo while underway;

(iv) a vessel engaged in the launching or recovery of aircraft;

(v) a vessel engaged in minesweeping operations;

(vi) a vessel engaged in a towing operation such as renders her unable to deviate from her course.

(h) The term "vessel constrained by her draught" means a power-driven vessel which because of her draught in relation to the available depth of water is severely restricted in her ability to deviate from the course she is following.

(i) The word "underway" means that a vessel is not at anchor, or /145
made fast to the shore, or aground.

(j) The words "length" and "breadth" of a vessel mean her length overall and greatest breadth.

(k) Vessels shall be deemed to be in sight of one another only when one can be observed visually from the other.

(l) The term "restricted visibility" means any condition in which visibility is restricted by fog, mist, falling snow, heavy rainstorms, sandstorms or any other similar causes.

Part B - Steering and Sailing Rules

Section 1. Conduct of Vessels in Any Condition of Visibility

Rule 4. Application

Rules in this Section apply in any condition of visibility.

Rule 5. Look-out

Every vessel shall at all times maintain a proper lookout by sight and hearing as well as by all available means appropriate in the prevailing

circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision.

Rule 6. Safe speed

Every vessel shall at all times proceed at a safe speed so that she can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions.

In determining a safe speed the following factors shall be among those taken into account:

(a) By all vessels: /146

(i) the state of visibility;

(ii) the traffic density including concentrations of fishing vessels or any other vessels;

(iii) the maneuverability of the vessel with special reference to stopping distance and turning ability in the prevailing conditions;

(iv) at night the presence of background light such as from shore lights or from back scatter of her own lights;

(v) the state of wind, sea and current, and the proximity of navigational hazards;

(vi) the draught in relation to the available depth of water.

(b) Additionally, by vessels with operational radar:

(i) the characteristics, efficiency and limitations of the radar equipment;

(ii) any constraints imposed by the radar range scale in use;

(iii) the effect on radar detection of the sea state, weather and other sources of interference;

(iv) the possibility that small vessels, ice and other floating objects may not be detected by radar at an adequate range;

(v) the number, location and movement of vessels detected by radar;

(vi) the more exact assessment of the visibility that may be possible when radar is used to determine the range of vessels or other objects in the vicinity.

Rule 7. Risk of collision

(a) Every vessel shall use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt such risk shall be deemed to exist.

(b) Proper use shall be made of radar equipment if fitted and operational, including long-range scanning to obtain early warning of risk of collision and radar plotting or equivalent systematic observation of /147
detected objects.

(c) Assumptions shall not be made on the basis of scanty information, especially scanty radar information.

(d) In determining if risk of collision exists the following considerations shall be among those taken into account;

(i) such risk shall be deemed to exist if the compass bearing of an approaching vessel does not appreciably change;

(ii) such risk may sometimes exist even when an appreciable bearing change is evident, particularly when approaching a very large vessel or a tow or when approaching a vessel at close range.

Rule 8. Action to avoid collision

(a) Any action taken to avoid collision shall, if the circumstances of the case admit, be positive, made in ample time and with due regard to the observance of good seamanship.

(b) Any alteration of course and/or speed to avoid collision shall, if the circumstances of the case admit, be large enough to be readily apparent to another vessel observing visually or by radar; a succession of small alterations of course and/or speed should be avoided.

(c) If there is sufficient sea room, alteration of course alone may be the most effective action to avoid a close-quarters situation provided that it is made in good time, is substantial and does not result in another close-quarters situation.

(d) Action taken to avoid collision with another vessel shall be

such as to result in passing at a safe distance. The effectiveness of the action shall be carefully checked until the other vessel is finally past and clear.

(e) If necessary to avoid collision or allow more time to assess the situation, a vessel shall slacken her speed or take all way off by stopping or reversing her means of propulsion. /148

Rule 9. Narrow channels

(a) A vessel proceeding along the course of a narrow channel or fairway shall keep as near to the outer limit of the channel or fairway which lies on her starboard side as is safe and practicable.

(b) A vessel of less than 20 meters in length or a sailing vessel shall not impede the passage of a vessel which can safely navigate only within a narrow channel or fairway.

(c) A vessel engaged in fishing shall not impede the passage of any other vessel navigating within a narrow channel or fairway.

(d) A vessel shall not cross a narrow channel or fairway if such crossing impedes the passage of a vessel which can safely navigate only within such channel or fairway. The latter vessel may use the sound signal prescribed in Rule 34(d) if in doubt as to the intention of the crossing vessel.

(e) (i) In a narrow channel or fairway when overtaking can take place only if the vessel to be overtaken has to take action to permit safe passing, the vessel intending to overtake shall indicate her intention by sounding the appropriate signal prescribed in Rule 34(c)(i). The vessel to be overtaken shall, if in agreement, sound the appropriate signal prescribed in Rule 34(c)(ii) and take steps to permit safe passing. If in doubt she may sound the signals prescribed in Rule 34(d).

(ii) This Rule does not relieve the overtaking vessel of her obligation under Rule 13.

(f) A vessel nearing a bend or an area of a narrow channel or fairway where other vessels may be obscured by an intervening obstruction /149 shall navigate with particular alertness and caution and shall sound the appropriate signal prescribed in Rule 34(e).

(g) Any vessel shall, if the circumstances of the case admit, avoid anchoring in a narrow channel.

Rule 10. Traffic separation schemes

(a) This Rule applies to traffic separation schemes adopted by the Organization.

(b) A vessel using a traffic separation scheme shall:

(i) proceed in the appropriate lane in the general direction of traffic flow for that lane;

(ii) so far as practicable keep clear of a traffic separation line or separation zone;

(iii) normally join or leave a traffic lane at the termination of the lane, but when joining or leaving from the side shall do so at as small an angle to the general direction of traffic flow as practicable.

(c) A vessel shall so far as practicable avoid crossing traffic lanes, but if obliged to do so shall cross as nearly as practicable at right angles to the general direction of traffic flow.

(d) Inshore traffic zones shall not normally be used by through traffic which can safely use the appropriate traffic lane within the adjacent traffic separation scheme.

(e) A vessel, other than a crossing vessel, shall not normally enter a separation zone or cross a separation line except:

(i) in cases of emergency to avoid immediate danger;

(ii) to engage in fishing within a separation zone. /150

(f) A vessel navigating in areas near the terminations of traffic separation schemes shall do so with particular caution.

(g) A vessel shall so far as practicable avoid anchoring in a traffic separation scheme or in areas near its terminations.

(h) A vessel not using a traffic separation scheme shall avoid it by as wide a margin as is practicable.

(i) A vessel engaged in fishing shall not impede the passage of any vessel following a traffic lane.

(j) A vessel of less than 20 meters in length or a sailing vessel shall not impede the safe passage of a power-driven vessel following a traffic lane.

Section 2. Conduct of Vessels in Sight of One Another

Rule 11. Application

Rules in this Section apply to vessels in sight of one another.

Rule 12. Sailing vessels

(a) When two sailing vessels are approaching one another, so as to involve risk of collision, one of them shall keep out of the way of the other as follows:

(i) when each has the wind on a different side, the vessel which has the wind on the port side shall keep out of the way of the other;

(ii) when both have the wind on the same side, the vessel which is to windward shall keep out of the way of the vessel which is to leeward;

(iii) if a vessel with the wind on the port side sees a vessel to windward and cannot determine with certainty whether the other vessel has the wind on the port or on the starboard side, she shall keep out of the way of the other.

(b) For the purposes of this Rule the windward side shall be deemed
to be the side opposite to that on which the mainsail is carried or, /151
in the case of a square-rigged vessel, the side opposite to that on
which the largest fore-and-aft sail is carried.

Rule 13. Overtaking

(a) Notwithstanding anything contained in the Rules of this Section any vessel overtaking any other shall keep out of the way of the vessel being overtaken.

(b) A vessel shall be deemed to be overtaking when coming up with another vessel from a direction more than 22.5 degrees abaft her beam, that is, in such a position with reference to the vessel she is overtaking, that at night she would be able to see only the sternlight of that vessel but neither of her sidelights.

(c) When a vessel is in any doubt as to whether she is overtaking another, she shall assume that this is the case and act accordingly.

(d) Any subsequent alteration of the bearing between the two vessels shall not make the overtaking vessel a crossing vessel within the

meaning of these Rules or relieve her of the duty of keeping clear of the overtaken vessel until she is finally past and clear.

Rule 14. Head-on-situation

(a) When two power-driven vessels are meeting on reciprocal or nearly reciprocal courses so as to involve risk of collision each shall alter her course to starboard so that each shall pass on the port side of the other.

(b) Such a situation shall be deemed to exist when a vessel sees the other ahead or nearly ahead and by night she could see the masthead lights of the other in a line or nearly in a line and/or both sidelights and by day she observes the corresponding aspect of the other vessel.

(c) When a vessel is in any doubt as to whether such a situation exists she shall assume that it does exist and act accordingly.

Rule 15. Crossing situation /152

When two power-driven vessels are crossing so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way and shall, if the circumstances of the case admit, avoid crossing ahead of the other vessel.

Rule 16. Action by give-way vessel

Every vessel which is directed by these Rules to keep out of the way of another vessel shall, so far as possible, take early and substantial action to keep well clear.

Rule 17. Action by stand-on vessel

(a) (i) Where by any of these Rules one of two vessels is to keep out of the way the other shall keep her course and speed.

(ii) The latter vessel may however take action to avoid collision by her maneuver alone, as soon as it becomes apparent to her that the vessel required to keep out of the way is not taking appropriate action in compliance with these Rules.

(b) When, from any cause, the vessel required to keep her course

and speed finds herself so close that collision cannot be avoided by the action of the give-way vessel alone, she shall take such action as will best aid to avoid collision.

(c) A power-driven vessel which takes action in a crossing situation in accordance with sub-paragraph (a)(ii) of this Rule to avoid collision with another power-driven vessel shall, if the circumstances of the case admit, not alter course to port for a vessel on her own port side.

(d) This Rule does not relieve the give-way vessel of her obligation to keep out of the way.

Rule 18. Responsibilities between vessels /153

Except where Rules 9, 10 and 13 otherwise require:

(a) A power-driven vessel underway shall keep out of the way of:

(i) a vessel not under command;

(ii) a vessel restricted in her ability to maneuver;

(iii) a vessel engaged in fishing;

(iv) a sailing vessel.

(b) A sailing vessel underway shall keep out of the way of:

(i) a vessel not under command;

(ii) a vessel restricted in her ability to maneuver;

(iii) a vessel engaged in fishing.

(c) A vessel engaged in fishing when underway shall, so far as possible, keep out of the way of:

(i) a vessel not under command;

(ii) a vessel restricted in her ability to maneuver.

(d) (i) Any vessel other than a vessel not under command or a vessel restricted in her ability to maneuver shall, if the circumstances of the case admit, avoid impeding the safe passage of a vessel constrained by her draught, exhibiting the signals in Rule 28.

(ii) A vessel constrained by her draught shall navigate with particular caution having full regard to her special condition.

(e) A seaplane on the water shall, in general, keep well clear of all vessels and avoid impeding their navigation. In circumstances, however, where risk of collision exists, she shall comply with the Rules of this Part.

Section 3. Conduct of Vessels in Restricted Visibility

Rule 19. Conduct of vessels in restricted visibility

(a) This Rule applies to vessels not in sight of one another when navigating in or near an area of restricted visibility.

(b) Every vessel shall proceed at a safe speed adapted to the pre- /154
vailing circumstances and conditions of restricted visibility. A power-driven vessel shall have her engines ready for immediate maneuver.

(c) Every vessel shall have due regard to the prevailing circumstances and conditions of restricted visibility when complying with the Rules of Section 1 of this Part.

(d) A vessel which detects by radar alone the presence of another vessel shall determine if a close-quarters situation is developing and/or risk of collision exists. If so, she shall take avoiding action in ample time, provided that when such action consists of an alteration of course, so far as possible the following shall be avoided:

(i) an alteration of course to port for a vessel forward of the beam, other than for a vessel being overtaken;

(ii) an alteration of course towards a vessel abeam or abaft the beam.

(e) Except where it has been determined that a risk of collision does not exist, every vessel which hears apparently forward of her beam the fog signal of another vessel, or which cannot avoid a close-quarters situation with another vessel forward of her beam, shall reduce her speed to the minimum at which she can be kept on her course. She shall if necessary take all her way off and in any event navigate with extreme caution until danger of collision is over.

Part C - Lights and Shapes

Rule 20. Application

(a) Rules in this Part shall be complied with in all weathers.

(b) The Rules concerning lights shall be complied with from sunset to sunrise, and during such times no other lights shall be exhibited, except such lights as cannot be mistaken for the lights specified in these Rules or do not impair their visibility or distinctive character, or interfere with the keeping of a proper lookout. /155

(c) The lights prescribed by these Rules shall, if carried, also be exhibited from sunrise to sunset in restricted visibility and may be exhibited in all other circumstances when it is deemed necessary.

(d) The Rules concerning shapes shall be complied with by day.

(e) The lights and shapes specified in these Rules shall comply with the provisions of Annex I to these Regulations.

Rule 21. Definitions

(a) "Masthead light" means a white light placed over the fore and aft centerline of the vessel showing an unbroken light over an arc of the horizon of 225 degrees and so fixed as to show the light from right ahead to 22.5 degrees abaft the beam on either side of the vessel.

(b) "Sidelights" means a green light on the starboard side and a red light on the port side each showing an unbroken light over an arc of the horizon of 112.5 degrees and so fixed as to show the light from right ahead to 22.5 degrees abaft the beam on its respective side. In a vessel of less than 20 meters in length the sidelights may be combined in one lantern carried on the fore and aft centerline of the vessel.

(c) "Sternlight" means a white light placed as nearly as practicable at the stern showing an unbroken light over an arc of the horizon of 135 degrees and so fixed as to show the light 67.5 degrees from right aft on each side of the vessel.

(d) "Towing light" means a yellow light having the same characteristics as the "sternlight" defined in paragraph (c) of this Rule.

(e) "All round light" means a light showing an unbroken light over an arc of the horizon of 360 degrees.

(f) "Flashing light" means a light flashing at regular intervals at a frequency of 120 flashes or more per minute.

Rule 22. Visibility of lights /156

The lights prescribed in these Rules shall have an intensity as specified in Section 8 of Annex I to these Regulations so as to be visible at the following minimum ranges:

(a) In vessels of 50 meters or more in length:

a masthead light, 6 miles;
a sidelight, 3 miles
a sternlight, 3 miles;
a towing light, 3 miles;
a white, red, green or yellow all-round light, 3 miles.

(b) In vessels of 12 meters or more in length but less than 50 meters in length:

a masthead light, 5 miles; except that where the length of the vessel is less than 20 meters, 3 miles;
a sidelight, 2 miles;
a sternlight, 2 miles;
a towing light, 2 miles;
a white, red, green or yellow all-round light, 2 miles.

(c) In vessels of less than 12 meters in length:

a masthead light, 2 miles;
a sidelight, 1 mile;
a sternlight, 2 miles;
a towing light, 2 miles;
a white, red, green or yellow all-round light, 2 miles.

Rule 23. Power-driven vessels underway

(a) A power-driven vessel underway shall exhibit:

(i) a masthead light forward;

(ii) a second masthead light abaft of and higher than the forward one; except that a vessel of less than 50 meters in length shall not be obliged to exhibit such light but may do so;

(iii) sidelights;

(iv) a sternlight.

(b) An air-cushion vessel when operating in the non-displacement mode shall, in addition to the lights prescribed in paragraph (a) of this Rule, exhibit an all-round flashing yellow light. /157

(c) A power-driven vessel of less than 7 meters in length and whose maximum speed does not exceed 7 knots may, in lieu of the lights prescribed in paragraph (a) of this Rule, exhibit an all-round white light. Such vessel shall, if practicable, also exhibit sidelights.

Rule 24. Towing and pushing

(a) A power-driven vessel when towing shall exhibit:

(i) instead of the light prescribed in Rule 23(a)(i), two masthead lights forward in a vertical line. When the length of the tow, measuring from the stern of the towing vessel to the after end of the tow exceeds 200 meters, three such lights in a vertical line;

(ii) sidelights;

(iii) a sternlight;

(iv) a towing light in a vertical line above the sternlight;

(v) When the length of the tow exceeds 200 meters, a diamond shape where it can best be seen.

(b) When a pushing vessel and a vessel being pushed ahead are rigidly connected in a composite unit they shall be regarded as a power-driven vessel and exhibit the lights prescribed in Rule 23.

(c) A power-driven vessel when pushing ahead or towing alongside, except in the case of a composite unit, shall exhibit:

(i) instead of the light prescribed in Rule 23(a)(i), two masthead lights forward in a vertical line;

(ii) sidelights;

(iii) a sternlight.

(d) A power-driven vessel to which paragraphs (a) and (c) of this Rule apply shall also comply with Rule 23(a)(ii).

(e) A vessel or object being towed shall exhibit:

(i) sidelights;

(ii) a sternlight; /158

(iii) when the length of the tow exceeds 200 meters, a diamond shape where it can best be seen.

(f) Provided that any number of vessels being towed or pushed in a group shall be lighted as one vessel.

(i) a vessel being pushed ahead, not being part of a composite unit, shall exhibit at the forward end, sidelights.

(ii) a vessel being towed alongside shall exhibit a sternlight and at the forward end, sidelights.

(g) Where from any sufficient cause it is impracticable for a vessel or object being towed to exhibit the lights prescribed in paragraph (e) of this Rule, all possible measures shall be taken to light the vessel or object towed or at least to indicate the presence of the unlighted vessel or object.

Rule 25. Sailing vessels underway and vessels under oars

(a) A sailing vessel underway shall exhibit:

(i) sidelights;
(ii) a sternlight.

(b) In a sailing vessel of less than 12 meters in length the lights prescribed in paragraph (a) of this Rule may be combined in one lantern carried at or near the top of the mast where it can best be seen.

(c) A sailing vessel underway may, in addition to the lights prescribed in paragraph (a) of this Rule, exhibit at or near the top of the mast, where they can best be seen, two all-round lights in a vertical line, the upper being red and the lower green, but these lights shall not be exhibited in conjunction with the combined lantern permitted by paragraph (b) of this Rule.

(d) (i) A sailing vessel of less than 7 meters in length shall, if practicable, exhibit the lights prescribed in paragraph (a) or (b) of this Rule, but if she does not, she /159
shall have ready at hand an electric torch or lighted lantern showing a white light which shall be exhibited in sufficient time to prevent collision.

(ii) A vessel under oars may exhibit the lights prescribed

in this Rule for sailing vessels, but if she does not, she shall have ready at hand an electric torch or lighted lantern showing a white light which shall be exhibited in sufficient time to prevent collision.

(e) A vessel proceeding under sail when also being propelled by machinery shall exhibit forward where it can best be seen a conical shape, apex downwards.

Rule 26. Fishing vessels

(a) A vessel engaged in fishing, whether underway or at anchor, shall exhibit only the lights and shapes prescribed in this Rule.

(b) A vessel when engaged in trawling, by which is meant the dragging through the water of a dredge net or other apparatus used as a fishing appliance, shall exhibit:

(i) two all-round lights in a vertical line, the upper being green and the lower white, or a shape consisting of two cones with their apexes together in a vertical line one above the other; a vessel of less than 20 meters in length may instead of this shape exhibit a basket;

(ii) a masthead light abaft of and higher than the all-round green light; a vessel of less than 50 meters in length shall not be obliged to exhibit such a light but may do so;

(iii) when making way through the water, in addition to the lights prescribed in this paragraph, sidelights and a sternlight.

(c) A vessel engaged in fishing, other than trawling, shall exhibit:

(i) two all-round lights in a vertical line, the upper being red and the lower white, or a shape consisting of two cones with apexes together in a vertical line one above the other; a vessel of less than 20 meters in length may instead of this shape exhibit a basket;

(ii) when there is outlying gear extending more than 150 meters horizontally from the vessel, an all-round white light or a cone apex upwards in the direction of the gear;

(iii) when making way through the water, in addition to the /160

lights prescribed in this paragraph, sidelights and a sternlight.

(d) A vessel engaged in fishing in close proximity to other vessels may exhibit the additional signals described in Annex II to these Regulations.

(e) A vessel when not engaged in fishing shall not exhibit the lights or shapes prescribed in this Rule, but only those prescribed for a vessel of her length.

Rule 27. Vessels not under command or restricted in their ability to maneuver

(a) A vessel not under command shall exhibit:

(i) two all-round red lights in a vertical line where they can best be seen;

(ii) two balls or similar shapes in a vertical line where they can best be seen;

(iii) when making way through the water, in addition to the lights prescribed in this paragraph, sidelights and a sternlight.

(b) A vessel restricted in her ability to maneuver, except a vessel engaged in minesweeping operations, shall exhibit:

(i) three all-round lights in a vertical line where they can best be seen. The highest and lowest of these lights shall be red and the middle light shall be white;

(ii) three shapes in a vertical line where they can best be seen. The highest and lowest of these shapes shall be balls and the middle one a diamond;

(iii) when making way through the water, masthead lights, sidelights and a sternlight, in addition to the lights prescribed in sub-paragraph (i);

(iv) when at anchor, in addition to the lights or shapes prescribed in sub-paragraphs (i) and (ii), the light, lights or shape prescribed in Rule 30.

(c) A vessel engaged in a towing operation such as renders her unable to deviate from her course shall, in addition to the lights or /161

shapes prescribed in sub-paragraph (b)(i) and (ii) of this Rule, exhibit the lights or shape prescribed in Rule 24(a).

(d) A vessel engaged in dredging or underwater operations, when restricted in her ability to maneuver, shall exhibit the lights and shapes prescribed in paragraph (b) of this rule and shall in addition, when an obstruction exists, exhibit:

(i) two all-round red lights or two balls in a vertical line to indicate the side on which the obstruction exists;

(ii) two all-round green lights or two diamonds in a vertical line to indicate the side on which another vessel may pass;

(iii) when making way through the water, in addition to the lights prescribed in this paragraph, masthead lights, sidelights and a sternlight;

(iv) a vessel to which this paragraph applies when at anchor shall exhibit the lights or shapes prescribed in sub-paragraphs (i) and (ii) instead of the lights or shape prescribed in Rule 30.

(e) Whenever the size of a vessel engaged in diving operations makes it impracticable to exhibit the shapes prescribed in paragraph (d) of this Rule, a rigid replica of the International Code flag "A" not less than 1 meter in height shall be exhibited. Measures shall be taken to ensure all-round visibility.

(f) A vessel engaged in minesweeping operations shall, in addition to the lights prescribed for a power-driven vessel in Rule 23, exhibit three all-round green lights or three balls. One of these lights or shapes shall be exhibited at or near the foremast head and one at each end of the fore yard. These lights or shapes indicate that it is dangerous for another vessel to approach closer than 1,000 meters astern or 500 meters on either side of the minesweeper.

(g) Vessels of less than 7 meters in length shall not be required to exhibit the lights prescribed in this Rule.

(h) The signals prescribed in this Rule are not signals of vessels in distress and requiring assistance. Such signals are contained in Annex IV to these Regulations.

Rule 28. Vessels constrained by their draught /162

A vessel constrained by her draught may, in addition to the lights prescribed for power-driven vessels in Rule 23, exhibit where they can best be seen three all-round red lights in a vertical line, or a cylinder.

Rule 29. Pilot vessels

(a) A vessel engaged on pilotage duty shall exhibit:

(i) at or near the masthead, two all-round lights in a vertical line, the upper being white and the lower red;

(ii) when underway, in addition, sidelights and a sternlight;

(iii) when at anchor, in addition to the lights prescribed in sub-paragraph (i), the anchor light, lights or shape.

(b) A pilot vessel when not engaged on pilotage duty shall exhibit the lights or shapes prescribed for a similar vessel of her length.

Rule 30. Anchored vessels and vessels aground

(a) A vessel at anchor shall exhibit where it can best be seen:

(i) in the fore part, an all-round white light or one ball;

(ii) at or near the stern and at a lower level than the light prescribed in sub-paragraph (i), an all-round white light.

(b) A vessel of less than 50 meters in length may exhibit an all-round white light where it can best be seen instead of the lights prescribed in paragraph (a) of this Rule.

(c) A vessel at anchor may, and a vessel of 100 meters and more in length shall, also use the available working or equivalent lights to illuminate her decks.

(d) A vessel aground shall exhibit the lights prescribed in paragraph (a) or (b) of this Rule and in addition, where they can best be seen:

(i) two all-round red lights in a vertical line; /163

(ii) three balls in a vertical line.

(e) A vessel of less than 7 meters in length, when at anchor or aground, not in or near a narrow channel, fairway or anchorage, or where other vessels normally navigate, shall not be required to exhibit the lights or shapes prescribed in paragraphs (a), (b) or (d) of this Rule.

Rule 31. <u>Seaplanes</u>

Where it is impracticable for a seaplane to exhibit lights and shapes of the characteristics or in the positions prescribed in the Rules of this Part she shall exhibit lights and shapes as closely similar in characteristics and position as is possible.

Part D - Sound and Light Signals

Rule 32. <u>Definitions</u>

(a) The word "whistle" means any sound signalling appliance capable of producing the prescribed blasts and which complies with the specifications in Annex III to these Regulations.

(b) The term "short blast" means a blast of about one second's duration.

(c) The term "prolonged blast" means a blast of from four to six seconds' duration.

Rule 33. <u>Equipment for sound signals</u>

(a) A vessel of 12 meters or more in length shall be provided with a whistle and a bell and a vessel of 100 meters or more in length shall, in addition, be provided with a gong, the tone and sound of which cannot be confused with that of the bell. The whistle, bell and gong shall comply with the specifications in Annex III to these Regulations. The /164
bell or gong or both may be replaced by other equipment having the same respective sound characteristics, provided that manual sounding of the required signals shall always be possible.

(b) A vessel of less than 12 meters in length shall not be obliged to carry the sound signalling appliances prescribed in paragraph (a) of this Rule but if she does not, she shall be provided with some other means of making an efficient sound signal.

Rule 34. <u>Maneuvering and warning signals</u>

(a) When vessels are in sight of one another, a power-driven vessel underway, when maneuvering as authorized or required by these Rules, shall indicate the maneuver by the following signals on her whistle:

- one short blast to mean "I am altering my course to starboard";
- two short blasts to mean "I am altering my course to port";
- three short blasts to mean "I am operating astern propulsion."

(b) Any vessel may supplement the whistle signals prescribed in paragraph (a) of this Rule by light signals, repeated as appropriate, while the maneuver is being carried out:

(i) these light signals shall have the following significance:

- one flash to mean "I am altering my course to starboard";
- two flashes to mean "I am altering my course to port";
- three flashes to mean "I am operating astern propulsion";

(ii) the duration of each flash shall be about one second, the interval between flashes shall be about one second, and the interval between successive signals shall be not less than ten seconds;

(iii) the light used for this signal shall, if fitted, be an all-round white light, visible at a minimum range of 5 miles, and shall comply with the provisions of Annex I.

(c) When in sight of one another in a narrow channel or fairway:

(i) a vessel intending to overtake another shall in compliance with Rule 9(e)(i) indicate her intention by the /<u>165</u>
following signals on her whistle:

- two prolonged blasts followed by one short blast to mean "I intend to overtake you on your starboard side";

- two prolonged blasts followed by two short blasts to mean "I intend to overtake you on your port side."

(ii) the vessel about to be overtaken when acting in accordance with Rule 9(e)(i) shall indicate her agreement by the following signal on her whistle:

- one prolonged, one short, one prolonged and one short blast, in that order.

(d) When vessels in sight of one another are approaching each other

and from any cause either vessel fails to understand the intentions or actions of the other, or is in doubt whether sufficient action is being taken by the other to avoid collision, the vessel in doubt shall immediately indicate such doubt by giving at least five short and rapid blasts on the whistle. Such signal may be supplemented by a light signal of at least five short and rapid flashes.

(e) A vessel nearing a bend or an area of a channel or fairway where other vessels may be obscured by an intervening obstruction shall sound one prolonged blast. Such signal shall be answered with a prolonged blast by any approaching vessel that may be within hearing around the bend or behind the intervening obstruction.

(f) If whistles are fitted on a vessel at a distance apart of more than 100 meters, one whistle only shall be used for giving maneuvering and warning signals.

Rule 35. Sound signals in restricted visibility

In or near an area of restricted visibility, whether by day or night, the signals prescribed in this Rule shall be used as follows:

(a) A power-driven vessel making way through the water shall sound /166 at intervals of not more than 2 minutes one prolonged blast.

(b) A power-driven vessel underway but stopped and making no way through the water shall sound at intervals of not more than 2 minutes two prolonged blasts in succession with an interval of about 2 seconds between them.

(c) A vessel not under command, a vessel restricted in her ability to maneuver, a vessel constrained by her draught, a sailing vessel, a vessel engaged in fishing and a vessel engaged in towing or pushing another vessel shall, instead of the signals prescribed in paragraphs (a) or (b) of this Rule, sound at intervals of not more than 2 minutes three blasts in succession, namely one prolonged followed by two short blasts.

(d) A vessel towed or if more than one vessel is towed the last vessel of the tow, if manned, shall at intervals of not more than 2 minutes sound four blasts in succession, namely one prolonged followed by three short blasts. When practicable, this signal shall be made immediately after the signal made by the towing vessel.

(e) When a pushing vessel and a vessel being pushed ahead are rigidly connected in a composite unit they shall be regarded as a power-driven vessel and shall give the signals prescribed in paragraphs (a) or (b) of this Rule.

(f) A vessel at anchor shall at intervals of not more than one minute ring the bell rapidly for about 5 seconds. In a vessel of 100 meters or more in length the bell shall be sounded in the forepart of the vessel and immediately after the ringing of the bell the gong shall be sounded rapidly for about 5 seconds in the after part of the vessel. A vessel at anchor may in addition sound three blasts in succession, namely one short, one prolonged and one short blast, to give warning of her position and of the possibility of collision to an approaching vessel.

(g) A vessel aground shall give the bell signal and if required the gong signal prescribed in paragraph (f) of this Rule and shall, in addition, give three separate and distinct strokes on the bell immedi- /167
ately before and after the rapid ringing of the bell. A vessel aground may in addition sound an appropriate whistle signal.

(h) A vessel of less than 12 meters in length shall not be obliged to give the above-mentioned signals but, if she does not, shall make some other efficient sound signal at intervals of not more than 2 minutes.

(i) A pilot vessel when engaged on pilotage duty may in addition to the signals prescribed in paragraphs (a), (b) or (f) of this Rule sound an identity signal consisting of four short blasts.

Rule 36. Signals to attract attention

If necessary to attract the attention of another vessel any vessel may make light or sound signals that cannot be mistaken for any signal authorized elsewhere in these Rules, or may direct the beam of her searchlight in the direction of the danger, in such a way as not to embarass any vessel.

Rule 37. Distress signals

When a vessel is in distress and requires assistance she shall use or exhibit the signals prescribed in Annex IV to these Regulations.

Part E - Exemptions

Rule 38. Exemptions

Any vessel (or class of vessels) provided that she complies with the requirements of the International Regulations for Preventing Collisions at Sea, 1960, the keel of which is laid or which is at a corresponding stage of construction before the entry into force of these Regulations may be exempted from compliance therewith as follows:

(a) The installation of lights with ranges prescribed in Rule 22, until four years after the date of entry into force of these Regulations.

(b) The installation of lights with color specifications as prescribed in Section 7 of Annex I to these Regulations, until four years after the date of entry into force of these Regulations. /168

(c) The repositioning of lights as a result of conversion from Imperial to metric units and rounding off measurement figures, permanent exemption.

(d) (i) The repositioning of masthead lights on vessels of less than 150 meters in length, resulting from the prescriptions of Section 3(a) of Annex I, permanent exemption.

(ii) The repositioning of masthead lights on vessels of 150 meters or more in length, resulting from the prescriptions of Section 3(a) of Annex I to these Regulations, until nine years after the date of entry into force of these Regulations.

(e) The repositioning of masthead lights resulting from the prestions of Section 2(b) of Annex I, until nine years after the date of entry into force of these Regulations.

(f) The repositioning of sidelights resulting from the prescriptions of Section 3(b) of Annex I, until nine years after the date of entry into force of these Regulations.

(g) The requirements for sound signal appliances prescribed in Annex III, until nine years after the date of entry into force of these Regulations.

ANNEX I

POSITIONING AND TECHNICAL DETAILS OF LIGHTS AND SHAPES

1. Definition

The term "height above the hull" means height above the uppermost continuous deck.

2. Vertical positioning and spacing of lights

(a) On a power-driven vessel of 20 meters or more in length the masthead lights shall be placed as follows:

(i) the forward masthead light, or if only one masthead light is carried, then that light, at a height above the hull of not less than 6 meters, and, if the breadth of the vessel exceeds 6 meters, then at a height above the hull not less than such breadth, so however that the light need not be placed at a greater height above the hull than 12 meters; /169

(ii) when two masthead lights are carried the after one shall be at least 4.5 meters vertically higher than the forward one.

(b) The vertical separation of masthead lights of power-driven vessels shall be such that in all normal conditions of trim the after light will be seen over and separate from the forward light at a distance of 1000 meters from the stern when viewed from sea level.

(c) The masthead light of a power-driven vessel of 12 meters but less than 20 meters in length shall be placed at a height above the gunwale of not less than 2.5 meters.

(d) A power-driven vessel of less than 12 meters in length may carry the uppermost light at a height of less than 2.5 meters above the gunwale. When, however, a masthead light is carried in addition to sidelights and a sternlight, then such masthead light shall be carried at least 1 meter higher than the sidelights.

(e) One of the two or three masthead lights prescribed for a power-driven vessel when engaged in towing or pushing another vessel shall be placed in the same position as the forward masthead light of a power-driven vessel.

(f) In all circumstances the masthead light or lights shall be so placed as to be above and clear of all other lights and obstructions.

(g) The sidelights of a power-driven vessel shall be placed at a height above the hull not greater than three quarters of that of the forward masthead light. They shall not be so low as to be interfered with by deck lights.

(h) The sidelights, if in a combined lantern and carried on a power-driven vessel of less than 20 meters in length, shall be placed not less than 1 meter below the masthead light.

(i) When the Rules prescribe two or three lights to be carried in a vertical line, they shall be spaced as follows: /170

(i) on a vessel of 20 meters in length or more such lights shall be spaced not less than 2 meters apart, and the

lowest of these lights shall, except where a towing light is required, not be less than 4 meters above the hull;

(ii) on a vessel of less than 20 meters in length such lights shall be spaced not less than 1 meter apart and the lowest of these lights shall, except where a towing light is required, not be less than 2 meters above the gunwale;

(iii) when three lights are carried they shall be equally spaced.

(j) The lower of the two all-round lights prescribed for a fishing vessel when engaged in fishing shall be at a height above the sidelights not less than twice the distance between the two vertical lights.

(k) The forward anchor light, when two are carried, shall not be less than 4.5 meters above the after one. On a vessel of 50 meters or more in length this forward anchor light shall not be less than 6 meters above the hull.

3. Horizontal positioning and spacing of lights

(a) When two masthead lights are prescribed for a power-driven vessel, the horizontal distance between them shall not be less than one half of the length of the vessel but need not be more than 100 meters. The forward light shall be placed not more than one quarter of the length of the vessel from the stern.

(b) On a vessel of 20 meters or more in length the sidelights shall not be placed in front of the forward masthead lights. They shall be placed at or near the side of the vessel.

4. Details of location of direction-indicating lights for fishing vessels, dredgers and vessels engaged in underwater operations /171

(a) The light indicating the direction of the outlying gear from a vessel engaged in fishing as prescribed in Rule 26(c)(ii) shall be placed at a horizontal distance of not less than 2 meters and not more than 6 meters away from the two all-round red and white lights. This light shall be placed not higher than the all-round white light prescribed in Rule 26(c)(i) and not lower than the sidelights.

(b) The lights and shapes on a vessel engaged in dredging or underwater operations to indicate the obstructed side and/or the side on which it is safe to pass, as prescribed in Rule 27(d)(i) and (ii), shall be placed at the maximum practical horizontal distance, but in

no case less than 2 meters, from the lights or shapes prescribed in Rule 27(b)(i) and (ii). In no case shall the upper of these lights or shapes be at a greater height than the lower of the three lights or shapes prescribed in Rule 27(b) (i) and (ii).

5. Screens for sidelights

The sidelights shall be fitted with inboard screens painted matt black, and meeting the requirements of Section 9 of this Annex. With a combined lantern, using a single vertical filament and a very narrow division between the green and red sections, external screens need not be fitted.

6. Shapes

(a) Shapes shall be black and of the following sizes:

(i) a ball shall have a diameter of not less than 0.6 meter;

(ii) a cone shall have a base diameter of not less than 0.6 meter and a height equal to its diameter; /172

(iii) a cylinder shall have a diameter of at least 0.6 meter and a height of twice its diameter;

(iv) a diamond shape shall consist of two cones as defined in (ii) above having a common base.

(b) The vertical distance between shapes shall be at least 1.5 meter.

(c) In a vessel of less than 20 meters in length shapes of lesser dimensions but commensurate with the size of the vessel may be used and the distance apart may be correspondingly reduced.

7. Color specification of lights

The chromaticity of all navigation lights shall conform to the following standards, which lie within the boundaries of the area of the diagram specified for each color by the International Commission on Illumination (CIE).

The boundaries of the area for each color are given by indicating the corner coordinates, which are as follows:

(i) White

x	0.525	0.525	0.452	0.310	0.310	0.443
y	0.382	0.440	0.440	0.348	0.283	0.382

(ii) Green

x	0.028	0.009	0.300	0.203
y	0.385	0.723	0.511	0.356

(iii) Red

x	0.680	0.660	0.735	0.721
y	0.320	0.320	0.265	0.259

(iv) Yellow

x	0.612	0.618	0.575	0.575
y	0.382	0.382	0.425	0.406

8. Intensity of lights /173

(a) The minimum luminous intensity of lights shall be calculated by using the formula:

$$I = 3.43 \times 10^6 \times T \times D^2 \times K_{-D}$$

where I is luminous intensity in candelas under service conditions,

T is threshold factor 2×10^{-7} lux,

D is range of visibility (luminous range) of the light in nautical miles,

K is atmospheric transmissivity.

For prescribed lights the value of K shall be 0.8, corresponding to a meteorological visibility of approximately 13 nautical miles.

(b) A selection of figures derived from the formula is given in the following table:

Range of visibility (luminous range) of light in nautical miles D	Luminous intensity of light in candelas for K = 0.8 I
1	0.9
2	4.3
3	12
4	27
5	52
6	94

Note: The maximum luminous intensity of navigation lights should be limited to avoid undue glare.

9. Horizontal Sectors

(a) (i) In the forward direction, sidelights as fitted on the vessel must show the minimum required intensities. The intensities must decrease to reach practical cut-off between 1 degree and 3 degrees outside the prescribed sectors.

(ii) For sternlights and masthead lights and at 22.5 degrees abaft the beam for sidelights, the minimum required intensities shall be maintained over the arc of the horizon up to 5 degrees within the limits of the sectors prescribed in Rule 21. From 5 degrees within the prescribed sectors the intensity may decrease by 50 per cent up to the prescribed limits; it shall decrease steadily to reach practical cut-off at not more than 5 degrees outside the prescribed limits.

(b) All-round lights shall be so located as not to be obscured by masts, topmasts or structures within angular sectors of more than 6 degrees, except anchor lights, which need not be placed at an impracticable height above the hull. /174

10. Vertical Sectors

(a) The vertical sectors of electric lights, with the exception of lights on sailing vessels shall ensure that:

(i) at least the required minimum intensity is maintained at all angles from 5 degrees above to 5 degrees below the horizontal;

(ii) at least 60 per cent of the required minimum intensity is maintained from 7.5 degrees above to 7.5 degrees below the horizontal.

(b) In the case of sailing vessels the vertical sectors of electric lights shall ensure that:

(i) at least the required minimum intensity is maintained at all angles from 5 degrees above to 5 degrees below the horizontal;

(ii) at least 50 per cent of the required minimum intensity is maintained from 25 degrees above to 25 degrees below the horizontal.

(c) In the case of lights other than electric these specifications shall be met as closely as possible.

11. Intensity of nonelectric lights

Nonelectric lights shall so far as practicable comply with the minimum intensities, as specified in the Table given in Section 8 of this Annex.

12. Maneuvering light

Notwithstanding the provisions of paragraph 2(f) of this Annex the maneuvering light described in Rule 34(b) shall be placed in the same fore and aft vertical plane as the masthead light or lights and, where practicable, at a minimum height of 2 meters vertically above the fore- /175
ward masthead light, provided that it shall be carried not less than 2 meters vertically above or below the after masthead light. On a vessel where only one masthead light is carried the maneuvering light, if fitted, shall be carried where it can best be seen, not less than 2 meters vertically apart from the masthead light.

13. Approval

The construction of lanterns and shapes and the installation of lanterns on board the vessel shall be to the satisfaction of the appropriate authority of the State where the vessel is registered.

ANNEX II

ADDITIONAL SIGNALS FOR FISHING VESSELS FISHING IN CLOSE PROXIMITY

1. General

The lights mentioned herein shall, if exhibited in pursuance of Rule 26(d), be placed where they can best be seen. They shall be at least 0.9 meter apart but at a lower level than lights prescribed in Rule 26 (b)(i) and (c)(i). The lights shall be visible all round the horizon at a distance of at least 1 mile but at a lesser distance than the lights prescribed by these Rules for fishing vessels.

2. Signals for Trawlers

(a) Vessels when engaged in trawling, whether using demersal or pelagic gear, may exhibit:

(i) when shooting their nets:
two white lights in a vertical line;

(ii) when hauling their nets:
one white light over one red light in a vertical line; /176

(iii) when the net has come fast upon an obstruction:
two red lights in a vertical line.

(b) Each vessel engaged in pair trawling may exhibit:

(i) by night, a searchlight directed forward and in the direction of the other vessel of the pair.

(ii) when shooting or hauling their nets or when their nets have come fast upon an obstruction, the lights prescribed in 2(a) above.

3. Signals for purse seiners

Vessels engaged in fishing with purse seine gear may exhibit two yellow lights in a vertical line. These lights shall flash alternately every second and with equal light and occultation duration. These lights may be exhibited only when the vessel is hampered by its fishing gear.

ANNEX III

TECHNICAL DETAILS OF SOUND SIGNAL APPLIANCES

1. Whistles

(a) Frequencies and range of audibility

The fundamental frequency of the signal shall lie within the range 70-700 Hz. The range of audibility of the signal from a whistle shall be determined by those frequencies, which may include the fundamental and/or one or more higher frequencies, which lie within the range 180-700 Hz (± 1 per cent) and which provide the sound pressure levels specified in paragraph 1(c) below.

(b) Limits of fundamental frequencies

To ensure a wide variety of whistle characteristics, the fundamental frequency of a whistle shall be between the following limits:

(i) 70-200 Hz, for a vessel 200 meters or more in length;

(ii) 130-350 Hz, for a vessel 75 meters but less than 200 meters in length; /177

(iii) 250-700 Hz, for a vessel less than 75 meters in length.

(c) Sound signal intensity and range of audibility

A whistle fitted in a vessel shall provide, in the direction of maximum intensity of the whistle and at a distance of 1 meter from it, a sound pressure level in at least one 1/3-octave band within the range of frequencies 180-700 Hz (± 1 per cent) of not less than the appropriate figure given in the table below.

Length of vessel in meters	1/3-octave band level at 1 meter in dB referred to 2×10^{-5} N/m^2	Audibility range in nautical miles
200 or more	143	2
75 but less than 200	138	1.5
20 but less than 75	130	1
Less than 20	120	0.5

The range of audibility in the table above is for information and is approximately the range at which a whistle may be heard on its forward axis with 90 per cent probability in conditions of still air on board a vessel having average background noise level at the listening posts (taken to be 68 dB in the octave band centered on 250 Hz and 63 dB in the octave band centered on 500 Hz).

In practice the range at which a whistle may be heard is extremely variable and depends critically on weather conditions: the values given can be regarded as typical but under conditions of strong wind or high ambient noise level at the listening post the range may be much reduced.

(d) Directional properties

The sound pressure level of a directional whistle shall be not more than 4 dB below the sound pressure level on the axis at any direction in the horizontal plane within ± 45 degrees of the axis. The sound pressure level at any other direction in the horizontal plane shall be not /178 more than 10 dB below the sound pressure level on the axis, so that the range in any direction will be at least half the range on the forward axis. The sound pressure level shall be measured in that 1/3-octave band which determines the audibility range.

(e) Positioning of whistles

When a directional whistle is to be used as the only whistle on a vessel, it shall be installed with its maximum intensity directed straight ahead.

A whistle shall be placed as high as practicable on a vessel, in order to reduce interception of the emitted sound by obstructions and also to minimize hearing damage risk to personnel. The sound pressure level of the vessel's own signal at listening posts shall not exceed 110 dB (A) and so far as practicable should not exceed 100 dB (A).

(f) Fitting of more than one whistle

If whistles are fitted at a distance apart of more than 100 meters, it shall be so arranged that they are not sounded simultaneously.

(g) Combined whistle systems

If due to the presence of obstructions the sound field of a single whistle or of one of the whistles referred to in paragraph 1(f) above is likely to have a zone of greatly reduced signal level, it is recommended that a combined whistle system be fitted so as to overcome this reduction. For the purpose of the Rules a combined whistle system is to be regarded as a single whistle. The whistles of a combined system shall be located at a distance apart of not more than 100 meters and

arranged to be sounded simultaneously. The frequency of any one whistle shall differ from those of the others by at least 10 Hz.

2. Bell or gong

(a) Intensity of signal

A bell or gong, or other device having similar sound characteristics shall produce a sound pressure level of not less than 110 dB at 1 meter.

(b) Construction

Bells and gongs shall be made of corrosion-resistant material and designed to give a clear tone. The diameter of the mouth of the bell shall be not less than 300 mm for vessels of more than 20 meters in length, and shall be not less than 200 mm for vessels of 12 to 20 meters in length. Where practicable, a power-driven bell striker is recommended to ensure constant force but manual operation shall be possible. The mass of the striker shall be not less than 3 per cent of the mass of the bell. /179

3. Approval

The construction of sound signal appliances, their performance and their installation on board the vessel shall be to the satisfaction of the appropriate authority of the State where the vessel is registered.

ANNEX IV

DISTRESS SIGNALS

1. The following signals, used or exhibited either together or separately, indicate distress and need of assistance:

   (a) a gun or other explosive signal fired at intervals of about a minute;

   (b) a continuous sounding with any fog-signalling apparatus;

   (c) rockets or shells, throwing red stars fired one at a time at short intervals;

   (d) a signal made by radiotelegraphy or by any other signalling method consisting of the group ...---... (SOS) in the Morse Code;

(e) a signal sent by radiotelephony consisting of the spoken word "Mayday";

(f) the International Code Signal of distress indicated by N. C.;

(g) a signal consisting of a square flag having above or below it a ball or anything resembling a ball;

(h) flames on the vessel (as from a burning tar barrel, oil barrel,/180 etc.)

(i) a rocket parachute flare or a hand flare showing a red light;

(j) a smoke signal giving off orange-colored smoke;

(k) slowly and repeatedly raising and lowering arms outstretched to each side;

(l) the radiotelegraph alarm signal;

(m) the radiotelephone alarm signal;

(n) signals transmitted by emergency position-indicating radio beacons.

2. The use or exhibition of any of the foregoing signals except for the purpose of indicating distress and need of assistance and the use of other signals which may be confused with any of the above signals is prohibited.

3. Attention is drawn to the relevant sections of the International Code of Signals, the Merchant Ship Search and Rescue Manual and the following signals:

(a) a piece of orange-colored canvas with either a black square and circle or other appropriate symbol (for identification from the air);

(b) a dye marker.

NAVIGATION /181

Section 7.1. Measurements and Plotting Data on Charts

1. Checking Own Measurements and Calculations

In measurements and calculations a constant check of one's own work is required:

- when making measurements (i.e. reading instruments), check should be made in order to be certain that there are no gross erross;

- check measurements made by one instrument against readings obtained from another instrument (courses from the standard compass should be checked against those obtained from a different course indicator; distances travelled according to the log should be checked against those calculated from speed and time, etc.);

- check calculations by repeating them and using different methods;

- check the operation of the dead reckoning tracer against manual plotting; check the reckoned or observed position; compare the depth obtained from the chart with the depth measured by the echo sounder; check the position of the ship determined by one method and compare it with that obtained with the use of different landmarks or by another method;

- having discovered an error which could jeopardize navigational safety--regardless of who may have made it--report it immediately to the Commanding Officer of the ship and take measures to prevent any possible dangerous consequences.

2. Characteristics of Errors in Measurements and the Accuracy With Which Ship's Position is Known

All measurements are unavoidably subject to random and systematic errors. In two successive measurements of a quantity, the random errors assume different values and can be different in sign; systematic errors either remain constant or change according to conditions used in measurements. /182

In order to compensate for systematic errors, the data of measurement are adjusted by using correction factors. But even after performing corrections, measurements still may contain residual systematic errors.

The numerical characteristic of a random or residual systematic error in measurement is its root-mean-square value σ (root-mean-square error). It can be assumed, with a probability of 68.3%, that the absolute value of the actual error will not exceed the value of σ; with a probability of 95.5%--it will not exceed the value of 2σ; and with a probability of 99.7%--the value of 3σ.

The root-mean-square value of the systematic error in the arithmetic mean of n measurements is equal to the root-mean-square value of the systematic error in a single measurement. The root-mean-square value of the random error in the arithmetic mean is equal to $\sigma_{(1)}/\sqrt{n}$, where $\sigma_{(1)}$ is the root-mean-square value of the random error in a single measurement.

The accuracy with which the position of a ship is known is described by the root-mean-square error M in the calculated or observed position. If the value of M is obtained correctly, then the actual error in the ship's position has a probability of about 65% of not exceeding the value of M; a probability of 96% of not exceeding the value of 2M; and a probability of 99.8% of not exceeding the value of 3M.

3. Course Indication

Course indicator corrections. A gyrocompass correction is subject to continuous random variations about its mean value which remains practically constant for an extended period of time (weeks or months). For an aperiodic compass the root-mean-square value σ_M of the deviations of the instantaneous correction value from the mean amounts to 0.2-0.3°; for a non-aperiodic compass, in the reference latitude (usually 60°) -- about 0.4°; in latitudes other than the reference latitude -- up to 0.7°. During rolling and pitching or following ship's maneuver, these deviations can increase by a factor of two or three. In correcting courses and bearings use is made of the gyrocompass mean correction value which, as a rule, is determined from observations over an extended period of time (3-4 hours). A single observation gives the instantaneous compass /183
correction value. A deviation exceeding $3\delta_m$ of the instantaneous correction value from the mean or a deviation exceeding σ_m from the arithmetic mean of four to six instantaneous values, determined over a period of 20-30 minutes, should be considered to be an indication of the change in the mean correction value of the compass and of the need of recalculating it.

The magnetic compass correction is, in degrees:

$$\Delta MC = d + \delta \tag{7.1}$$

where d is the magnetic declination in degrees and δ is the compass deviation in degrees.

The magnetic declination is taken from the chart in the area of navigation of the ship; it must be adjusted to the navigation year (the annual variation in declination is indicated on the chart). The deviation is selected from the table of deviations (for each magnetic compass) according to the magnetic or compass course (when calculating the magnetic course). The deviation can vary significantly and must be redetermined after diving of the submarine to a great depth, following electric welding jobs, or with a significant change in the latitude of the area of navigation, etc.

The correction for the azimuth gyro, if the latter is being corrected by the gyro or magnetic compass, is equal to the correction for that compass. If the azimuth gyro is operating without such a correction, then its own correction is, in degrees:

$$\Delta AG = \Delta C_0 + \alpha t \tag{7.2}$$

where ΔC_0 is the correction of the compass with which the azimuth gyro was operating, degrees;

α is the azimuth gyro drift rate, degrees/min;

t is the interval of time after the joint operation began, min.

The rate of the azimuth-gyro drift can be determined from the following:

- from two corrections ΔAG_1 and ΔAG_2 and from the interval of time t between their determinations

$$\alpha = \frac{\Delta AG_2 - \Delta AG_1}{t} \tag{7.3}$$

- by constructing a graph representing the difference between courses. Every 10 minutes during a period of time of 3-4 hours, different courses are recorded from gyrocompass CC_{GC} and azimuth gyro CC_{AG}. In the /184 scale 10 min = 1 cm and 0.2° = 1 cm, the points corresponding to the differences $CC_{GC} - CC_{AG}$ are plotted and then connected by a smooth curve, i.e., a smoothing straight line is drawn. The ordinates and the difference in the abscissas of two arbitrary points on this line are substituted in Formula (7.3).

The calculation of the true course (TC) and true bearing (TB) from values obtained by measurement is as follows:

$$TC = CC + \Delta C \quad (7.4)$$

$$TB = CB + \Delta C \quad (7.5)$$

$$TB = TC + RB \quad (7.6)$$

where CB is the compass bearing, and RB is the relative bearing.

Only the corrected values (such as the true course and true bearing) are plotted on the chart. In using Formula (7.6) the relative bearing to starboard is considered positive and the relative bearing to port negative. The relative bearing in the angular measure (reading clockwise from 0 to 360°) is considered positive; if the result obtained by using Formula (7.6) exceeds 360°, then 360° must be subtracted from it.

In modern course-indicating systems the calculation of the true course from Formula (7.4) is performed automatically. The correction ΔC is fed into the corrector by hand; the true course repeaters show the magnitude $CC + \Delta C$. If, with the correction $\Delta_1 C$ introduced into the corrector, the correction of the course indicating system, determined from the true course repeater, becomes equal to $\Delta_2 C$, then the setting for the corrector must be changed by $\Delta_2 C$ so that the overall correction introduced into the corrector is $\Delta C = \Delta_1 C + \Delta_2 C$.

Calculation of the compass course, compass bearing, and relative bearing from values obtained from the chart is as follows:

$$CC = TC - \Delta C; \quad (7.7)$$

$$CB = TB - \Delta C; \quad (7.8)$$

$$RB = TB - TC. \quad (7.9)$$

In calculating the compass course from the magnetic compass it is first necessary to calculate the magnetic course:

$$MC = TC - d; \quad (7.10)$$

and then select the deviation, according to the magnetic course, from the table and calculate the compass course as follows:

$$CC = MC - \delta. \quad (7.11)$$

As a check, one should compute the compass correction from Formula (7.1) and the compass course from Formula (7.7). /185

Determining Course-Indicator Corrections

1. From the bearing of the range whose true direction is known (obtained from the sailing directions, the manual "Lights and Shapes", or taken from the chart) or from the bearing of a celestial body whose calculated azimuth during the direction finding is assumed to be the true bearing (see Section 8.4), or from the bearing of a distant object whose true bearing is known (taken from the well-known position of the ship on the chart), the correction is:

$$\Delta C = TB - CB \tag{7.12}$$

2. By comparison with another compass:

- at exactly the same time (on commands "Stand by" and "Zero") note the readings of both compasses;

- from Formula (7.4) calculate the true course by using the readings of the compass whose correction is known; and then

- calculate the correction of the other compass

$$\Delta C = TC - CC \tag{7.13}$$

Checking the Accuracy of Keeping the Prescribed Course

1. Check systematically how the helmsman keeps the prescribed course.

2. Check to make sure that compass corrections are made regularly:

- determine the correction as frequently as possible (if the situation permits upon relieving the watch, in the middle of the watch, and before coming off the watch);

- compare the readings of the standard compass with those of the standby course indicators periodically (if the course has remained unchanged according to one compass but has changed according to the other, correction should be made of one of them);

- make sure that the helmsman, upon completing a turn onto a new course, notes and sets on the indicator (or records on a board) the course given by the standby course indicator, and that he checks, at least once every 10 minutes, whether or not it remains constant.

All changes detected in compass correction must be reported to the Commanding Officer and navigator immediately and their values determined as soon as possible.

4. Calculating the Distance Run by a Ship /186

The distance run by a ship relative to the water is calculated from log readings. For checking purposes, however, the distance is calculated from the speed of the ship and time. The log readings are recorded with an accuracy of up to 0.1 nautical miles. The distance S_L traveled, in miles, according to the log is:

$$S_L = k_L \cdot D_L = [1 + \Delta L] \cdot D_L{}^1 \qquad (7.14)$$

where $k_L = 1 + \Delta L$ is the log coefficient;

$D_L = LR_2 - LR_1$ is the difference in log readings, miles; and

ΔL is the log correction, %.

The speed of the V_L in knots according to the log (i.e. the speed relative to the water) is:

$$V_L = k_L L \qquad (7.15)$$

where $L = D_L/t$ is the rate of increase in log readings with respect to time, knots.

The value of the log correction depends on the speed of the ship. The calculation of S_L from Formula (7.14) can be performed as follows:

- by multiplying k_L by D_L on a slide rule (Fig. 7.1);

- by using Tables 28a and 28b of the 1963 Nautical Tables (MT-63);

- mentally (approximately); after multiplying the number of tens of miles in the log reading difference by the log correction percentage value, find the correction for the distance covered, in cables lengths and add it to D_L, if the log correction is positive, or subtract it, if the log correction is negative.

In order to find the value of D_L from the distance S_k taken from the chart, divide S_k by k_L on the slide rule or use Tables 28a and 28b /187
(MT-63).

The corrector of a modern log performs calculations indicated in Formula (7.14) automatically. The log correction is fed into the corrector manually. The log repeaters indicate the distance traveled and adjusted by means of the log correction. In some dead reckoning tracers and logs the log correction is introduced in knots:

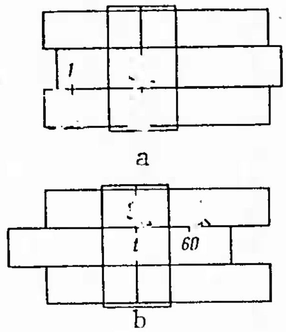


Fig. 7.1. Calculation of the distance run by a ship:
a - from the log; b - from the speed in knots and time in minutes

$$\Delta V_L = L'\Delta L. \tag{7.16}$$

The speed of the ship according to the speed of rotation of the propellers V_r in knots (speed relative to the water) is:

$$V_r = V_c + \Delta V_w + \Delta V_b + \Delta V_t = \Delta V_f \tag{7.17}$$

where V_c is the speed in the calm sea and with normal displacement (taken from the Tables showing the relationship between ship's speed and the speed of rotation of the propellers), knots;

ΔV_w is the correction for changes in speed due to the wind effects, knots;

ΔV_b is the correction for changes in speed due to the seaway effects, knots;

ΔV_t is the correction for deviations in the displacement from the normal, knots;

ΔV_f is the correction for fouling of the underwater part of the hull, knots.

The distance S_r in miles from the speed of the ship and the time is:

$$S_r = V_r t = \frac{V_r t'}{60} = \frac{V_r t''}{3600} \tag{7.18}$$

where t - time, hours;

t' - time, min;

t" - time, sec.

The calculations by using Formula (7.18) are performed on a slide rule (see Fig. 7.1), with the help of Tables 27a and 27b (MT-73), or mentally, bearing in mind that 1 cable length/min = 6 knots and 1 knot = 1/6 cables length/min. A significant discrepancy in distance S_L traveled, calculated from the log, and distance S_r, calculated from the speed and time, can be the result of an error in calculations, which should be carefully checked.

If the cause for the discrepancy is not found, then the position /188
obtained must be considered doubtful and, at the first opportunity, the accuracy of calculations must be checked (i.e. ship's position determined).

5. Using a Nautical Chart

When standing watch the officer of the watch must use the most up-to-date large-scale charts (as a rule, duplicates of the charts used by the navigator), corrected according to all Notices to Mariners received aboard ship before her departure and according to Navigational Notices to Mariners transmitted by radio.

The officer of the watch must have an excellent knowledge of conventional symbols used on nautical charts and maps. In using a nautical chart he must first familiarize himself with its heading (area covered by the chart, the scale, the year to which the magnetic declination refers, its annual variation, and the units in which heights are expressed). He must pay his attention to the layout of framed sections on the chart (how many angular minutes correspond to one division), to warnings, data on the geodetic base of the chart, the year of publication and dates of major and minor corrections. He must also adjust the magnetic declination to the present navigation year.

Ordinarily, nautical charts use the Mercator projection. The scale on such charts is not constant--it increases with an increase in latitude. In making measurements and plotting ranges on a nautical chart, the points of the dividers are placed at the side line of the frame on the chart or at the kilometer scale located beyond the side line at approximately that latitude in which the segment to be measured is located.

Section 7.2. Dead Reckoning

1. Dead Reckoning Without Taking Drift and Currents Into Account

Dead reckoning must begin as soon as a ship weighs anchor (casts off) and be continued without interruption until the ship is anchored or

moored. A line representing ship's course is drawn from the last observed or calculated point at an angle (to the meridians of the chart) equal to the true course calculated by means of Formula (7.4). Along /189 this line, one writes the compass course CC and the compass correction (in parentheses) (Fig. 7.2). Then, along the course line, one marks off the distance S_L run by the ship and determined from the log. The point thus obtained is indicated by a short line drawn perpendicularly to the course line. Next to this point one writes a fraction in which the numerator represents the time (with an accuracy of up to one minute for a speed of less than 12 knots; of up to 0.5 min for a speed of 12 to 24 knots; and with an accuracy of up to 0.1 min for a speed of more than 24 knots) while the denominator represents the log reading with an accuracy of up to 0.1 miles.

Taking the turning circle into account:

a) graphic method (Fig. 7.2): mark the position of the ship when the turn begins. From this mark measure off the radius of the turning circle $R_ц$ along the line perpendicular to the original course. Using the point 0 thus obtained as a center, describe an arc with a radius $R_ц$ and draw a new line for the course tangent to the arc. Drop a perpendicular to the course line from point 0 and use the point of intersection as the end point of the turn:

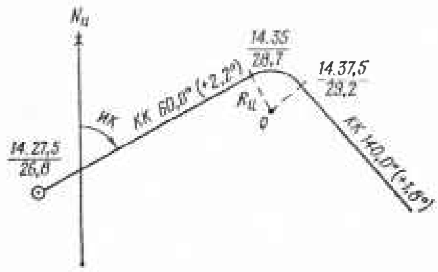


Fig. 7.2. Graphic dead reckoning without taking into account drift and currents.

b) tabular method (Fig. 7.3): from the point where the turn begins draw the line of the intermediate course $TC_i = 0.5(TC_1 + TC_2)$; along this line mark off the intermediate sailing distance d, selected from Table 30 (MT-63) by using the distance S traveled while turning, and the turning angle $\alpha = TC_2 - TC_1$.

Turning is not taken into account when course variations are less /190 than 30°. The line of the new course is constructed from the point corresponding to the beginning of the turn.

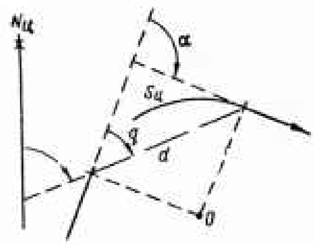


Fig. 7.3. Elements of the turning circle.

2. Taking Wind Drift Into Account

The drift angle α due to wind is the angle between the ship's centerplane (course line) and her heading relative to the water. If the wind blows against the port side of the ship the drift angle is positive; if it blows against the starboard side--the drift angle is negative. The path (path angle ΠY_α) is the direction along which the ship moves relative to the water:

$$\Pi Y_\alpha = TC + \alpha \tag{7.19}$$

The true course (TC) which should be such that the path angle is equal to the required angle taken from the chart is:

$$TC = \Pi Y_\alpha - \alpha \tag{7.20}$$

In taking wind drift into account only the line of the path, forming angle ΠY_α with the meridians, is plotted on the chart. The log takes into account changes in speed of the ship due to the wind effect, with the distance S_L or S_r run by the ship marked off along the line of the path. All notes and marks showing the positions determined are made along the path line only. With automatic reckoning, the drift angle α is fed into the corrector of the dead reckoning tracer by hand. In the old dead reckoning tracer models which do not have any provision for inserting the angle α, this angle is introduced by means of the "Compass correction" lever (the setting on the "Compass correction" scale must be equal to $\Delta GK + \alpha$).

The drift angle depends on the course angle and the velocity of the relative wind as well as on the speed and draft of the ship. It is taken either from tables or nomograms (compiled from the full scale trial data on wind drift angles obtained for ships of the same class) or measured by a driftmeter. /191

3. Taking Currents Into Account

The data on the velocity and direction of currents which can be expected at a given moment and given point in the sea and which are obtained from atlases and charts of currents, atlases of physico-geographical data from sailing directions, and navigational charts, are:

- data on constant currents; these data are obtained from the latitude and longitude of a given point;

- data on periodic (tidal) currents; these data are obtained from the latitude and longitude of a given point and the tidal time (the integral number of hours before or after high tide at the given point);

- data on aperiodic currents (due to the wind effect or other episodic factors); these data are obtained from the latitude and longitude of a given point and from the nature of the wind field.

All manuals consider that the direction of currents is the direction toward which a mass of water is moved by the flow (the current "flows out of the compass"). If no wind current data are available the velocity of the wind current in latitudes ranging from 30 to 70° can be assumed to be equal 0.3 knots for each wind velocity of 10 m/sec while its direction, in contrast to the direction of the wind vector, is 45° to the right in the northern hemisphere and 45° to the left in the southern hemisphere. In order to determine the full current vector from the constant, tidal, and wind components, one must add these components vectorially (some manuals cite the vector sum of the constant and tidal or wind components). The parameters of a current can also be measured by means of navigational instruments for measuring currents or they can be calculated from the differences in the readings of the absolute and relative logs. When sailing in an area with significant currents, the position of the ship and depth should be determined as often as possible and other precautionary measures taken.

The absolute velocity vector (the velocity of a ship relative to the land surface) is the geometric sum of the velocity vector of the ship relative to the water and the velocity vector of the current. When taking currents into account the following problems are encountered.

1. Given the true course, the velocity V_L of a ship relative to /192
the water or V_r, and the velocity vector $\bar{v}_T$ of the current. Find the direction of motion and velocity of the ship relative to the earth's surface (Fig. 7.4). From the starting point draw a line representing the path taking into account the drift ΠY_α or, if the drift is not taken into account, draw the true course line; along this line, in an arbitrary

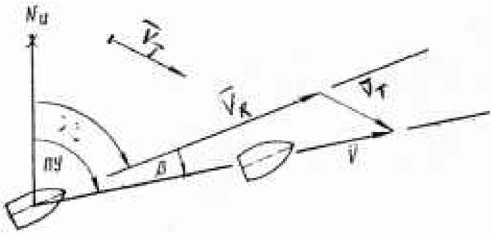


Fig. 7.4. Finding ПУ

scale, mark off ship's speed V_L taken from the log or calculated from the speed of rotation of the screw. At the end of this segment, mark off the velocity vector $\bar{v}_T$ of the current in the same scale.. The straight line drawn from the starting point to the end of the current vector is called the line of the path. It represents the direction of motion of the ship relative to the earth's surface. The angle ПУ between the direction of the true meridian and the line of the path is the path of the ship (the path angle). The angle β between the line of the path, taking the drift into account (if the drift is not considered, then between the line of the course), and the line of the path is the drift angle due to current. The drift angle due to current is not taken from the chart but is calculated as follows:

$$\beta = ПУ - ПУ\alpha \quad \text{or} \quad \beta = ПУ - TC \qquad (7.21)$$

2. Find the true course which one should assign in order for the ship to move along a given path relative to the earth's surface (Fig. 7.5). From the starting point 0 draw the line of the ship's path. Also from this point plot the velocity vector $\bar{v}_T$ of the current. From the end of this vector, mark a distance equal to the speed of the ship V_r or V_L (in the same scale) along the path line using the dividers. From the initial point 0, parallel to the line AB obtained, draw the path line taking only the wind drift into account (if the wind drift is not taken into account, this line will be the line of the course). /193
The compass course which one should assign is calculated from Formulas (7.20) and (7.7). If the wind drift is not taken into account, the compass course is calculated from Formula (7.7) while the drift angle is calculated from Formula (7.21).

When turning onto a different course or changing the speed, or when either the direction or velocity of the current changes, the above graphical solutions should be performed anew. To verify the results,

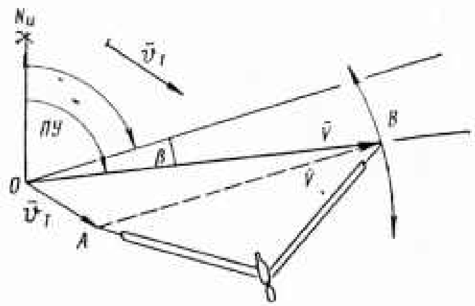


Fig. 7.5. Finding the true course.

one should check each time whether or not the following equality is satisfied:

$$CC + \Delta C + \alpha + \beta = \Pi Y \qquad (7.22)$$

In order to plot the dead reckoning position on the chart (Fig. 7.6) it is necessary to mark off the distance S_L (taken from the log or calculated from the speed of the screw) along the line of the path, taking into account only the drift ΠY_α (if the drift is not taken into account, mark off the distance run along the course line). Through the new point thus obtained draw a line parallel to the velocity vector of the current and, at its point of intersection with the line of path ΠY, locate the dead reckoning point. Next to this point write a fraction representing the time and log reading. The compass course, compass correction, and the total drift angle $c = \alpha + \beta$ are recorded along the line of the path (if the drift is not taken into account, then record the drift angle β due to current). In modern dead reckoning tracers the current is taken into account automatically, with the velocity and direction of the current inserted manually.

If it is necessary to estimate the log reading and time when a ship will be abeam or at a given distance from a landmark (Fig. 7.7), /194

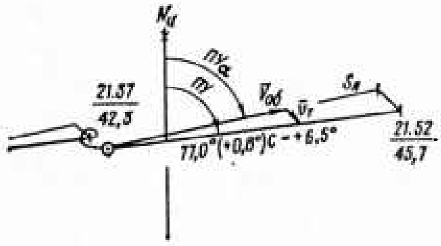


Fig. 7.6. Plotting a course taking into account the drift and current

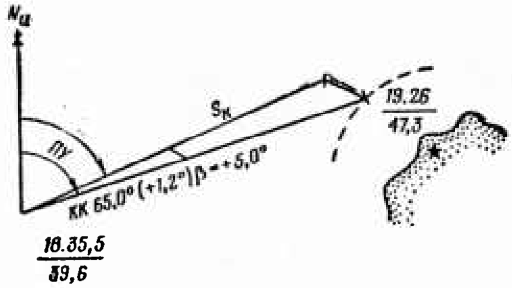


Fig. 7.7. Calculating the time and log readings when the range to a landmark is equal to that specified.

the dead reckoning point must first be found at the intersection of the line of the path with the bearing line (which is calculated from Formula 7.6) or with a circle corresponding to the given distance. Then, by drawing a straight line whose direction is opposite to that of the current, plot the auxiliary new point on the line of the path, taking into account only the drift (if the drift is not taken into account, then plot the point on the course line). Following this, measure the distance S_k between this point and the starting point and, setting $S_k = S_L = S_r$, calculate both the difference in log readings and the time interval. After adding them to the initial values, find the required log reading and time. /195

4. Accuracy of Dead Reckoning and of the Position Obtained

The rms error M_c in dead reckoning, in nautical miles, which can accumulate during an interval of time t, in hours, is:

$$M_c = \sqrt{k_1 t + k_2 t^2} \tag{7.23}$$

or more roughly:

$$M_c = K_c \sqrt{t} \tag{7.24}$$

where k_1, k_2, and K_c are coefficients depending on the area and sailing conditions, seaworthiness of the ship, her navigational instruments, etc. in miles x $(\text{hours})^{-0.5}$.

The values of the coefficients k_1, k_2 and K_c are determined empirically. For a ship that does not have absolute logs, the value K_c lies within the (0.5 to 2 miles) x $(\text{hours})^{-0.5}$.

The rms error of a dead reckoning position, in nautical miles, is:

$$M = \sqrt{M_0^2 + M_c^2}, \tag{7.25}$$

where M_0 is the rms error of the last observation in miles and M_c is the rms error of dead reckoning in miles.

Section 7.3. Determining the Position of the Ship From Visually Observed Landmarks

1. Visibility Range of Landmarks

The geometric (geographic) visibility range of objects is, in nautical miles:

$$Д_B = 2.08x(\sqrt{e} + \sqrt{h}) = x(Д_e + Д_h) \tag{7.26}$$

where x is the correction factor taking into account the resolution of the eye*; /196

* A. G. Gamov. Visibility Range of Objects at Sea in Daytime. Sudovozhdeniye, No. 2, 1962, Publishing House "Morskoy Transport," Leningrad, 1962.

e is the height of the observer's eye, m;

h is the height of the object observed, m;

$Д_e$ is the visible horizon range from the height of the observer's eye, miles;

$Д_h$ is the visible horizon range from the height of the object, miles.

The relationship between the correction factor x and the height h of an object, given a resolution of 1' for the eye, is:

h, meters	10	15	20	30	40	60	80	100
X	0.82	0.86	0.88	0.90	0.91	0.93	0.94	0.94

When calculating the visibility range of a light one should assume that x = 1.

The optical visibility range of a light in clear weather depends on the intensity of the light source. Nautical charts and manuals Lights and Shapes indicate the lesser of the two visibility ranges (geometric or optic). The geometric visibility range is given for a height of 5 m for the eye. If $Д_k$ is the geometric visibility range indicated on the chart, then with a height e for the eye, the visibility range of a light, in miles, is:

$$Д_B = Д_k + (Д_e - 4.7) \qquad (7.27)$$

The visibility range can be significantly reduced due to mist, fog, rain, or snowfall as well as due to a low degree of contrast in objects (intensity of lights).

The geometric radar visibility range of objects is, in miles:

$$Д_p = 2.22(\sqrt{e} + \sqrt{h}) = Д_{pe} + Д_{ph} \qquad (7.28)$$

where $Д_{pe}$ is the radar horizon range from the height of the radar antenna, miles;

$Д_{ph}$ is the radar horizon range from the height of the object, miles.

For small objects with poor reflective properties, the radar range /197
can be considerably less than that obtained from Formula (7.28). The radar range also depends on the condition of the atmosphere and must be adjusted in accordance with the forecast.

Tables 22a and b (MT-63) have been compiled from Formulas (7.26) for x = 1 and (7.28).

2. Selecting a Method of Determining the Position of the Ship and Landmarks

An effort should always be made to determine ship's position by using the most accurate methods which are also rather simple and reliable and which make it possible to check the measuring accuracy and plotting of measurements on charts. Other conditions being equal, observations become more accurate under the following conditions:

- the position is determined from the landmarks closest to the ship; and

- the difference in bearings of two adjacent landmarks is close to 90° when determining the position from two or four landmarks, and close to 120° when determining the position from three landmarks.

The determination of the position from two position lines (two bearings, a bearing and a distance, two distances, etc.) should be resorted to only if it is impossible to obtain a third position line.

The accuracy in identifying landmarks is a necessary condition for a reliable observation. Landmarks are identified by comparing their characteristics with data provided in sailing directions and in the manuals Lights and Shapes and Electronic Aids. A stop watch must be used to identify lights on the basis of their periods. The drawings and photographs contained in the sailing directions should be used to identify visible and radar landmarks. Identification of landmarks can also be aided by the use of their bearings taken from the dead reckoning position of the ship indicated on the chart.

The observed position, if obtained as a result of the simultaneous or of the almost simultaneous measurements of navigational parameters (bearings, distances, angles), is marked by a point with a small circle around it. If it is obtained from position lines at different times (cross-bearing, cross-distance, etc.) it is marked by a point placed in a triangle. Observations made with the use of electronic aids are /198 additionally marked by an arrow; the data obtained with sonar aids are underlined with a wavy line and those obtained from astronomical observations are placed in two circles around them.

Following determination of the position, the dead reckoning position corresponding to the observation time must be marked on the chart and the discrepancy indicated. The time and log reading should be written in the form of a fraction next to the observed point. If the discrepancy exceeds the value obtained from Formula (7.25) by a factor of two or three, then the accuracy of the dead reckoning and of all the observations and calculations must be checked. If no error is found, determination of the position should be made by using a different method or by employing a different combination of landmarks. In

order to check the accuracy of observations, the echo sounder should also be used (together with the measurement of bearings, distances, etc., measure the depth and compare it with that given on the chart at the observed point; if there is a large discrepancy in depths consider the observation inaccurate or doubtful).

3. Accuracy of Determining Ship's Position

The rms displacement of the position line in miles is:

$$m = \frac{\Delta n}{\Delta U} \sigma_U \qquad (7.29)$$

where Δn is the distance between two adjacent isolines or position lines, miles;

ΔU is the difference in values of the navigational parameter to which they correspond, miles;

σ_U is the rms error of measuring the navigational parameter, miles.

The rms error M_0 of determining the location of a ship from two position lines, taking into account only the effect of random errors in measurements, is:

$$M_0 = km^* \qquad (7.30)$$

where k is the coefficient obtained from Table 7.1, and

m* is the rms displacement of the less accurate position line, miles.

Table 7.1 /199

Values of the coefficient k obtained from the ratio m'/m* of the rms displacements of the more accurate and less accurate position lines and their intersection angle θ

m'/m*	Position line intersection angle θ in degrees							
	20 160	30 150	40 140	50 130	60 120	70 110	80 100	90
0	2.9	2.0	1.6	1.3	1.2	1.1	1.0	1.0
0.2	3.0	2.0	1.6	1.3	1.2	1.1	1.0	1.0
0.4	3.1	2.1	1.7	1.4	1.2	1.1	1.1	1.1
0.6	3.4	2.3	1.8	1.5	1.3	1.2	1.2	1.2
0.8	3.7	2.6	2.0	1.7	1.5	1.4	1.3	1.3
1.0	4.1	2.8	2.2	1.8	1.6	1.5	1.4	1.4

If the systematic errors of measurements are commensurate with the random errors and σ_U is the rms value of their sum, then the use of Table 7.1 and Formula (7.30) results in a somewhat distorted picture about the accuracy of observations.

If the position of the ship is being determined from three or four position lines, the accuracy of observation can be evaluated by considering only two of the more accurate lines whose intersection angle is closer to 90°. An increase in the number of position lines up to three or four increases the accuracy of observation by no more than 20 or 30%, respectively. However, the increase makes it possible to detect gross errors when making measurements or plotting the results, i.e., it makes the observation more reliable.

4. Determining Ship's Position From Two Angles

After making the sextant ready for observations (see Section 8.1) and identifying three landmarks, measure and record the horizontal angles between the left and center and between the center and right landmarks. Note and record the log reading and time. If the speed of the ship is high and the angles are measured slowly, refer the observations to the same instant of time (to the time at which the second angle was measured), i.e., measure the first angle twice (before and after measuring the second) and compute its mean value. Correct the /200
sextant readings by means of the index and instrument corrections as follows:

$$\alpha = SR_1 + (i + s); \quad \beta = SR_2 + (i + s) \qquad (7.31)$$

Set the measured angles α and β on the protractor with the left angle on the left and the right angle on the right (if a protractor is not available plot them on tracing paper). Place the protractor (or tracing paper) on the chart so that the beveled edges of the rulers (lines drawn on the tracing paper) pass through the centers of the landmarks (Fig. 7.8). Make a pinhole in the center of the protractor (common vertex of the angles on the tracing paper) and mark the fix obtained.

If the ship is close to the circle passing through the three landmarks selected for observation, then the fix will be inaccurate (a case of uncertainty). In order to avoid this, draw roughly a circle on the chart passing through the landmarks and if the position determined is close to the circle, select different landmarks.

To evaluate the observation accuracy it is necessary to measure on the chart the distance Д_{Π} to the left landmark, Д_{C} to the center landmark, Д_{Π} to the right landmark, as well as the distance d_{Π} between

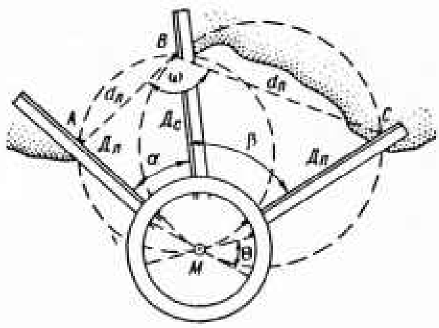


Fig. 7.8. Determination of position from two angles.

the center and left landmarks and the distance d_{Π} between the center and right landmarks. After drawing roughly the circles to include angles α and β (as shown in Fig. 7.8), measure the angle θ of their intersection or calculate it from the formula $\theta = 360° - (\alpha + \beta + \omega)$, /201
where ω is the angle at the center landmark between the lines representing the directions to the other landmarks. Calculate the ratios $k_L = \text{Д}_{\Pi}/d_{\Pi}$ and $k_R = \text{Д}_{\Pi}/d_{\Pi}$ and mark the greater ratio k_{max}.

The effect of random measurement errors is expressed as the rms error of determining the position of the ship in cable lengths as follows:

$$M_0 = 0.25 \frac{k_{max}\text{Д}_c}{\sin\theta} \sigma_a \qquad (7.32)$$

where Д_c is the distance to the center landmark in miles;

σ_a is the rms error in measuring and plotting the angles in degrees (if the protractor is used, the error can be assumed to be 0.1°; if tracing paper is used, 0.2°); and

θ is the angle of intersection of position lines in degrees.

Table 7.2

Rms error in determining ship's position (in cable lengths) from two horizontal angles or from two bearings with $\sigma_a = \sigma_b = 1°$ (effect of random errors of measurements)

$k_{max}\Delta_c$ or Δ_{max}, in miles	Angle θ of the intersection of position lines, degrees							
	20 160	30 150	40 140	50 130	60 120	70 110	80 100	90
1	0.7	0.5	0.4	0.3	0.3	0.3	0.3	0.3
2	1.5	1.0	0.8	0.7	0.6	0.5	0.5	0.5
4	2.7	2.0	1.6	1.3	1.2	1.1	1.0	1.0
6	4.4	3.0	2.3	2.0	1.7	1.6	1.5	1.5
8	5.9	4.0	3.1	2.6	2.3	2.1	2.0	2.0
10	7.3	5.0	3.9	3.3	2.9	2.7	2.5	2.5
20	14.6	10.0	7.8	6.5	5.8	5.3	5.1	5.0

Remarks

1. Use the value $k_{max}\Delta_c$ in the left column of the table when determining the position from two angles and the value Δ_{max} when determining the position from two bearings.

2. If the rms error of measuring angles (bearings) is by a factor of n less than the value of $\sigma_a = \sigma_b = 1°$ for which the table was compiled, then the value M_0 will be less by the same factor.

3. If the value of $k_{max}\Delta_c$ or Δ_{max} is increased by a factor of n, then the value of M_0 is increased by the same factor. /202

4. If the ratios k_l and k_R or the distances to the left or right landmarks differ considerably in determining the position from bearings, the table will give a somewhat exaggerated (up to 20-30%) value of M_0.

5. Determining Ship's Position From Bearings of Several Landmarks Measured Simultaneously

It is preferred that the determination of ship's position be made from bearings of three or four landmarks because in determining position from two landmarks the accuracy of measurements and plotting cannot be checked. Determination of the position from two bearings is justified

only if it is impossible to determine it by means of the more reliable methods (if only two landmarks are visible and it it is impossible to measure their ranges).

After selecting and identifying the landmarks, measure, in quick succession, and record their bearings and note and record the log reading and the time. Bearings are taken first of those landmarks whose relative bearings are closer to 0° (180°). At night one takes bearings first of the less visible landmarks (flashing lights). If the ship is moving at a high speed and the bearings are measured slowly, measurements should be referred to the same time, i.e., measure the bearings of the first, second, and third landmarks and then measure once again the bearings of the second and first landmarks and calculate their average values.

After correcting the compass bearings, draw the bearing lines from the appropriate landmarks on the chart. The point of intersection of these lines is the fix of the ship.

If, in determining the position by three or four landmarks, the lines of the bearings do not intersect at one point and form a figure of errors whose sides are less than 5 mm in the scale of the chart, then the fix is marked in the center of this figure. If the sides of the figure of errors exceed 5 mm, then the accuracy of identifying landmarks, measurements, and calculations must be checked and the determination repeated by using different landmarks. If the position and dimensions of the figure of errors do not change after several successive measurements in which a fixed combination of landmarks was used with no errors in identifying landmarks, correcting and plotting of bearings, the error is usually then in the compass correction which /203
must be checked and determined at the first opportunity.

The root-mean-square error in determining the position of the ship from two bearings, taking into account only random errors of measurement, can be evaluated with the aid of Table 7.2 or from the following formula:

$$M_{0(2)} = 0.25 \frac{\text{Д}_{max}}{\sin\theta} \cdot \sigma_E \qquad (7.33)$$

where $M_{0(2)}$ is the rms error in cable lengths;

Д_{max} is the range to the most distant landmark, miles;

σ_E is the rms value of random errors of measuring bearings in degrees (if the gyrocompass is used the error is between 0.4° and 0.6°; for the magnetic compass it is between 0.8 and 1.5°) and

θ is the difference in bearings of the landmarks, degrees.

Table 7.3

Rms error in determining the position of the ship (in cable lengths) from two bearings with $\sigma_S = 1°$

(effect of the recurrent systematic error of measurements)

max in miles	Angle θ of the intersection of position lines, degrees						
	30	50	70	90	110	130	150
1	0.2	0.2	0.2	0.3	0.3	0.4	0.7
2	0.4	0.4	0.4	0.5	0.6	0.8	1.4
4	0.7	0.8	0.9	1.0	1.2	1.6	2.7
6	1.1	1.2	1.3	1.5	1.8	2.5	4.0
8	1.4	1.5	1.7	2.0	2.4	3.3	5.4
10	1.8	1.9	2.1	2.5	3.0	4.1	6.7
20	3.6	3.9	4.3	5.0	6.1	8.3	13.5

The effect of the recurrent systematic error of measurement (the same for all bearings) is evaluated from the expression for the rms error of determining ship's position, in cable lengths:

$$M_{0(2)S} = 0.175 \frac{Д_{max}}{\cos \theta/2} \cdot \sigma_S \tag{7.34}$$

where σ_S is the rms value of the recurrent systematic error of measuring bearing in degrees (if the gyrocompass is used the error ranges from /204
0.5 to 1.6°; for the magnetic compass, 0.8 to 1.5°).

The rms error of determining the position, taking into account the effect of the recurrent systematic error and random measurement errors is:

$$M_{0(2)} \sqrt{M_{(2)} + M_{0(2)S}} \tag{7.35}$$

6. Determining Ship's Position From Bearings of a Single or Several Landmarks Measured at Different times

After obtaining a bearing the first time, record the bearing, log reading and time. If the bearing changes by an angle of at least 30°, it is measured again and the log reading and time are noted and recorded. The compass corrected bearings are plotted on the chart. The vector S_{12}

of the absolute (relative to the earth's surface) motion of the ship during the interval of time between bearing measurements is plotted from an arbitrary point C (Fig. 7.9), along the line of the first bearing (when sailing in a current, the current is taken into account, see Section 7.2). From the new point E obtained, a straight line is drawn parallel to the line of the first bearing until it intersects the line of the second bearing. The point M thus obtained is marked by a triangle. /205

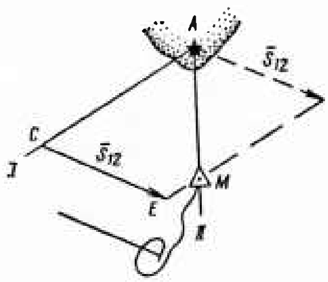


Fig. 7.9. Determining ship's position by the cross-bearing method.

The same plots are constructed when determining the position from bearings of two landmarks (Fig. 7.10) obtained at different times. Line I^1 is the first position line referred to the point of measurement of the second bearing.

The rms error of determining the position is, in cable lengths:

$$M_o = \sqrt{M^2_{0\,(2)} + \frac{M^2_c}{2\sin^2\theta}}, \tag{7.36}$$

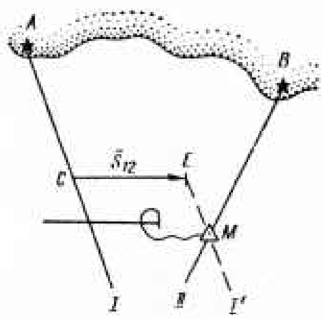


Fig. 7.10. Determining ship's position from bearings of two landmarks, taken at different times.

where $M_{0(2)}$ is the value obtained from Formula (7.35) in cable lengths;

M_c is the rms calculation error, accumulated over the time interval between measurements of bearings, and calculated from Formula (7.24), in cable lengths;

θ is the difference in bearings of landmarks, in degrees.

7. Determining Ship's Position From Ranges to the Reference Points

After measuring the ranges to several reference points, we draw arcs of circles on the chart whose centers are the reference points and whose radii are equal to the ranges measured (in the scale of the chart). At the point of intersection of the arcs we obtain the position of the /206 ship. If the arcs do not intersect at one point, the position is assumed to be in the center of the figure of errors. If the figure is large (its sides on the chart are greater than 5 mm), the accuracy of landmark identification, measurements, and plotting must be checked.

If the range is measured by means of a range finder or radar whose scales are graduated in gunnery cable lengths, one should, before plotting, express the range in navigational cable lengths by multiplying the data of measurements by 0.987 or by using Table 45a (MT-63).

To determine the range from the vertical angle, the sextant must be made ready for observation (see Section 8.1), the vertical angle between the line of the horizon (base of the object) and top of the object must be measured and the sextant readings adjusted by using the following formula:

$$\gamma = SR + (i + s) \qquad (7.37)$$

The distance then can be calculated by using Table 29 (MT-63) or a slide rule:

$$Д_\gamma = 1.86\,\frac{h}{\gamma} \qquad (7.38)$$

where $Д_\gamma$ is the distance, miles;

h is the height of object, m;

γ is the vertical angle, min.

If the base of the object is hidden behind the horizon (i.e., if the range to the object exceeds the visibility range of the horizon), then Formula (7.38) may not be used.

The rms error of determining the position from the distance to two landmarks is calculated from Formula (7.30) and Table 7.1 (it should be taken into account that the rms displacements of the position lines are equal to the rms errors of measuring distances; if the measurements are equally accurate, then $m'/m^* = 1.0$; the angle of intersection of the position lines is equal to the difference in bearings of the landmarks).

Section 7.4. The Use of Radio and Sonar Equipment /207

1. Using an Echo Sounder

Depth measured by means of an echo sounder is corrected for the submergence of the echo sounder transducers below the surface of the water (the correction is always positive; for a submerged submarine it is equal to the sum of the submarine depth and the height of the full buoyancy waterline above the submarine base plane); for the deviation of the velocity of sound from the theoretical velocity (obtained from special tables or charts); and for the sea level when the echo sounder is used in determining the position of a ship (it is always negative and numerically equal to the height of the tide, see Section 10.2).

In order to determine the position of a ship from the contour of the sea bottom, a number of depth soundings should be made and the time and log readings recorded for each depth sounding. On tracing paper, draw a meridian line and ship's course line. From an arbitrary point on the course line mark off the distances run by the ship from the initial time to the time of the next depth measurement. Next to each point obtained record the depth (the corrected depth), time, and the log reading.

On the chart draw with a pencil additional isobaths (Fig. 7.11) corresponding to the depths recorded on the tracing paper. Place the tracing paper on the chart and move it so that the meridian line on the tracing paper is parallel to the meridians on the chart, with the

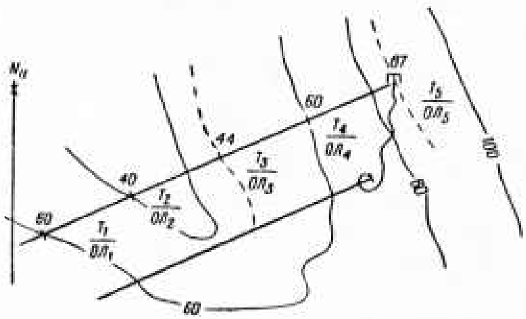


Fig. 7.11. Determining position from depths.

points on the tracing paper coinciding with the appropriate isobaths on the chart. For checking purposes, remove the tracing paper and match the points once again. Mark the point corresponding to the last depth measurement with the conventional symbol (shown in Fig. 7.11), record the time and log readings and indicate the discrepancy. For an efficient determination of the position the following should be observed:

- the depths on the chart should be plotted from measurements obtained with sufficient accuracy and detail;

- the depths in the area of navigation should not be too similar, differing only slightly from one another; however, they should not change too sharply and irregularly either;

- of all the isobaths used there should be at least two whose directions at the points of intersection with the course line would differ by an angle of not less than 30°.

The bearing (the radio bearing or the astronomical position line) and the depth measured by an echo sounder offer sometimes the only opportunity of determining ship's position when approaching the shore from the sea (i.e., of finding the intersection of the isobath, corresponding to the measured depth, and the bearing line). However, the position thus obtained requires careful checking. /208

Ordinarily, measuring depths with an echo sounder makes it possible to obtain timely warnings when coming dangerously close to the shore, shallow waters, or other navigational hazards. The comparison of depths measured by an echo sounder with those indicated on the chart is one of the most effective methods of detecting errors of observation of dead reckoning. Nothing can justify idleness on the part of the watch officer who is not making the timely use of the echo sounder when approaching a shore or shoal or when the ship's position is in doubt, if there are no special circumstances preventing depth measurements.

2. Determining Ship's Position from Radio Bearings

Information on radio beacons such as the frequency or wavelength, recognition signal or the operating time from which one can determine ship's position is obtained from the manual Electronic Navigational Aids for the corresponding sea (or area of the ocean). After switching on the radio direction finder, tune it to the frequency of the radio station whose bearing is to be obtained. When finding the direction in the listening mode, by successively turning the goniometer indicator knob for compensating the antenna effect, obtain the sharpest angle of silence, set the indicator at its center and take the radio bearing reading from the variable scale and the radio course angle reading from the fixed scale (with an accuracy of 1°) and record the time and log readings. /209

In automatic direction finding, after tuning to the frequency of the radio beacon and making sure that there is no interference from the nearby frequencies, set the operating mode switch at position A. With the goniometer needle indicating the bearing position, take the radio bearing and radio course angle readings. When determining bearing by means of a two-channel visual direction finder, make control checks and tune to the frequency of the radio beacon. After setting the sighting lines parallel to the major axis of the ellipse on the display, take the radio bearing (RB) and radio course angle readings.

The loxodromic bearing lines (Lox B) are plotted on the chart through the points representing the radio beacons:

$$\text{Lox B} = \text{RB} + f + \Delta\text{GC} + \psi \tag{7.39}$$

Using the radio course angle readings one obtains the radio deviation f from tables of radio deviations for the corresponding submarine operating conditions (full-buoyancy, diving trim, periscope depth) and the frequency range of the radio beacon whose bearing is being obtained. If the goniometer carries the radio-deviation curve, then its magnitude is noted on the scale of the goniometer indicator right after measurements of the radio bearing.

Formula (7.39) takes into account the correction ΔGC of the gyrocompass which feeds the compass course to the radio direction finder. The orthodromic correction ψ is obtained from Table 23b, MT-63 by using the latitude of the position of the ship and from the difference in longitudes between the radio beacon and the position of the ship. In the Northern hemisphere the correction is positive for bearings ranging from 0 to 180° and negative for bearings ranging from 180 to 360°. In the Southern hemisphere its signs are reversed.

The bearing lines plotted on the chart should be referred to the point of measurement of the last bearing (see Section 7.3, Subsection 6, and Fig. 7.10). The accuracy of measurements is evaluated from /210
Formula (7.33) or from Table 7.2. The rms error of radio direction finding may be assumed to be equal to 0.7 to 1.9° in daytime and 0.8 to 3.5° at night (the smaller values correspond to ranges less than 50 miles to the radio beacons, to the presence of a sharp minimum, and to the absence of sharp variations in bearing, indicating the influence of the night effect).

3. Using Combined Radio Beacons

A radio beacon bearing is measured by means of a marine radio direction finder. The distance to an air-type or a water-type acoustic radiator is determined from the interval of time between the reception of the radio and synchronized sound signals or from the number of short

dashes received by radio prior to the reception of the synchronized sound signal. The line of bearing is plotted on the chart from the radio beacon while the range is plotted from the acoustic radiator. Information on frequencies, operating schedules, recognition signals and on the method for determining range is given in the manual Electronic Navigational Aids.

4. Using Sector-type Radio Beacons

After obtaining radio-beacon data, i.e., the frequency and identification signal, from the manual Electronic Navigational Aids, tune a radio receiver of the appropriate range or a radio direction finder operating in the panoramic reception mode to this frequency and begin to receive signals. The radio beacon first transmits identification signals, then a long dash for measuring bearings and, finally, directional signals for a period of 30 seconds. Depending on the sector in which the ship is located, first dots will be heard and then dashes or, vice versa, first dashes and then dots. If no signal is missed during the reception, then their total number should be 60. Measurements involve counting of the number of signals received before they fade away (before crossing the equisignal zone) by one of the following methods.

1. Using the KI-55 indicator. After switching on the indicator adjust brightness and focus. By means of the "Amplification" control obtain the greatest change in signal amplitudes in the equisignal zone. By turning the "Scan" knob, join the beginning of the first signal with the end of the last signal. Set the zero line of the transparent scale at the beginning of the first signal and take a reading from that /211
range of the scale where the equisignal zone is observed (the amplitudes of the dashes and dots are equal). Note and record which signals (dots or dashes) were received first.

2. Aural monitoring. Note and record which signals (dots or dashes) were heard at the beginning of a cycle. Count the number of them (n') received before they ceased to be audible and count the number (n'') of the opposite signals (dashes or dots) received after the signals became distinguishable once again. Calculate the number of missed signals from

$$\Delta = 60 - (n' + n'') \tag{7.40}$$

For plotting, use the signals which were heard initially and correct their number by one-half the number of missed signals:

$$n = n' + \frac{\Delta}{2} \tag{7.41}$$

3. Using a pointer-type indicator and a stop watch. A voltmeter or a multirange test set connected to the output of the receiver is used as an indicator. Adjust the receiver gain so that when crossing the equisignal zone the amplitude of oscillations of its needle would undergo its sharpest change. With the beginning of the reception of directional signals (oscillations of the needle) turn on the stop watches. Stop the first watch when the oscillations of the needle subside and stop the second watch when they resume. Note which signals were received at the beginning of the cycle and count them:

$$n = t_1 + t_2 \tag{7.42}$$

where t_1 and t_2 are stop watch readings, sec.

After receiving the signals of the first radio beacon, tune to the frequency of the second radio beacon and, as before, count the number of signals received before crossing the equisignal zone; then, if possible, do the same for the third radio beacon, etc. The results of measurements can be plotted on a chart by using one of the following methods.

1. Using a radio navigation chart with isolines. Locate and mark the isoline closest to the dead reckoning position of the ship, i.e., the isoline corresponding to the number of signals n from the first radio beacon, received before their audibility faded away (with the number of signals corrected by one-half the number of missed signals); then do the same for the second radio beacon, etc. If the required isoline is not on the chart, draw it in with a pencil. /212

2. Using the tables in the manual Electronic Navigational Aids.

After finding the sector in which the ship is located on the radio beacon sector diagram, select the ship's orthodromic bearing (obtained from the beacon) from the table by using the sector number and the number of signals n received before their audibility faded away and corrected by one-half of the number of signals missed. Adjust the bearing using the orthodromic correction and plot the line of the orthodromic bearing thus determined on the chart.

3. Using special tables containing the coordinates of the points of intersection of the isolines with the parallels and meridians of the chart. After finding on the diagram the sector of the radio beacon in which the ship is located, select from the table, by using the sector number, the number of received signals (dots or dashes) and the latitude of the parallel on the chart, the longitude of the point of intersection of the isoline with this parallel (or by using the longitude of the meridian, select the latitude of the point of intersection of the isoline with the meridian). Plot several (no less than two)

such points on the chart and connect them with a smooth curve.

Repeat this procedure for the second and third radio beacon. Refer the bearing lines (isolines) plotted on the chart to the point where the last bearing was taken (see Section 7.3, Subsection 6). Inasmuch as the same number of identical signals can be received in various sectors of a radio beacon, special attention should be given to the identification of the sector. To do this, use should be made of not only the dead reckoning data but also of the radio beacon bearing measurements.

The rms error of determining the position of a ship from two radio beacons can be evaluated by using Formulas (7.29) and (7.30), and Table 7.1. Moreover, the rms error of measurements can be assumed to be equal to 1 or 2 signals in daytime, and 2 to 5 signals at night.

5. The Use of Ship Radars

The position of a ship can be determined from reference points (individual small islands, cliffs, moles, berths, and other man-made structures) by means of a radar from bearings or ranges. With only one reference point observed, the position can be determined from its bear- /213
ing and range. For small ranges to reference points (less than 20 to 30 cable lengths) bearings yield a better accuracy in determining the position. For checking purposes, however, one should measure both the bearings and ranges. If the reference point is a radar transponder beacon, then the range must be measured to the first (closest to the center of the sweep) reply signal. The range measured should always be adjusted by using the negative correction obtained from the description of the radio beacon given in the manual Electronic Navigational Aids. The accuracy of measurement can be determined from Formulas (7.29) and (7.30), and from Tables 7.1 and 7.2. Moreover, for the navigational radar the rms error of measuring bearings can be assumed to be between 0.7 and 1.9°. The error of measuring range, when using the variable range rings, may be assumed to be 0.6 to 1% of the range measured.

In determining the position of a ship with the aid of separate landmarks, one should measure the ranges to the landmarks closest to the ship, preferably to the steep precipitous areas of the shore. Set the variable range ring so that it touches the image of the shore, i.e., measure the ranges to the echo signals closest to the ship (Fig. 7.12). Also, in order to facilitate the identification of reference points, take bearings of the points of tangency. The measurements can be plotted on the chart by using two methods.

1. Draw a meridian line on tracing paper; from an arbitrary point, used as a center, draw arcs of circles with radii equal (in the scale of the chart) to the ranges measured and, to identify the reference points, draw the bearing lines. Place the tracing paper over the chart

(Fig. 7.13) and move it to the right and left and up and down until the arcs drawn on the tracing paper touch the shoreline. Make a pinhole at the center of the arcs and mark the fix.

2. On the chart, draw arcs of circles (with the radii equal to the ranges measured) from the points on the shoreline, identified as the points of tangency to which the ranges were measured (Fig. 7.14). At their point of intersection mark the fix. If the arcs do not intersect at one point and form a figure of errors then, if the figure is small, mark the fix at its center. If the figure of errors is large, repeat the determination of the position of the ship.

Whenever the ranges measured exceed the radar horizon range it should be assumed that the ship is actually closer to the shore than the measured position plotted on the chart indicates, because ranges were measured not up to the shoreline but to regions on the shore located beyond the shoreline. /215

Determining the position of a ship by using the "Palma" matching unit. After switching on the matching unit, set up the scale range corresponding to the scale indicated in the heading of the chart. Switch on the fixed range rings and set the chart with its side frame under the semitransparent glass so that the center of the sweep is at a latitude approximately corresponding to the area in which the ship is navigating. After aligning the range rings with the lines on the side frame of the chart, turn the "Adjustable scale" knot so that the scale of the image is exactly equal to that of the chart.

After switching off the range rings, place the chart with the area in which the ship is navigating under the semitransparent glass and move it right and left and up and down so that the radar image coincides with the contours of the shoreline on the chart. Matching of the reference points should be done first by using the shoreline sections /216
closest to the ship. Mark the position of the ship in the center of the sweep. If the steep precipitous areas of the shore are used as landmarks which are accurately plotted on the chart and located at a distance (from the ship) which is within the radar horizon range, then the rms error of determining the position of the ship will be between 0.5 cable lengths (on charts with a scale of 1:50 000) and 2 cable lengths (on charts with a scale of 1:200 000).

6. The Use of Shore-based Radars

A ship requiring services of a pilot establishes two-way radio communication (usually on ultrashort waves) with a shore-based radar station and makes a request, indicating the time piloting is to begin, the ship's position (bearing and distance from a reference point), course and speed. If this data is insufficient for the shore station

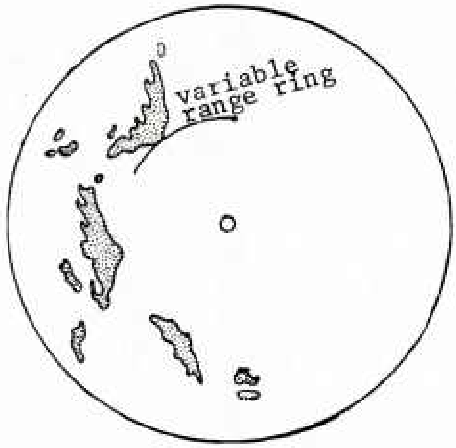


Fig. 7.12. Determining the position from landmarks; measurement of ranges on PPI

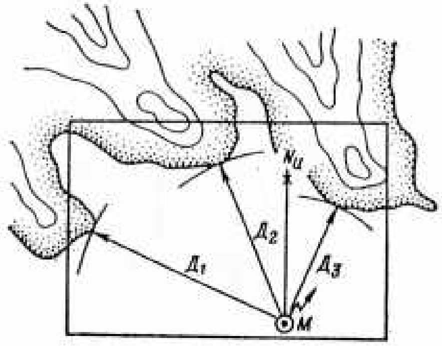


Fig. 7.13. Determining the position from landmarks and plotting the measured point on the chart (Method 1)

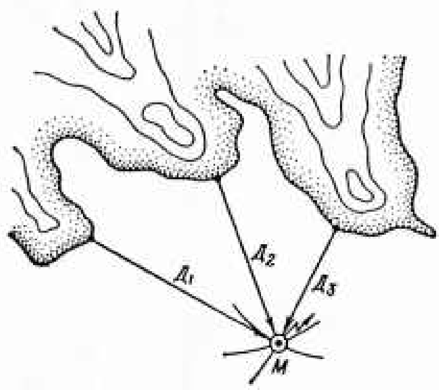


Fig. 7.14. Determining the position from landmarks and plotting the measured point on the chart (Method 2)

to identify the ship to be piloted, then the ship executes a recognition manuever (usually a temporary change in course on signal from the shore). The subsequent operation may be carried out by using the following two methods.

1. Data on the position of the ship being piloted. These data are usually transmitted in the form of bearings and distances, either directly from the shore station or from a reference point (beacon or shape marked on the chart). From these data the positions of the ship are plotted on the chart and used as regular measurements. At the same time information is transmitted to the piloted ship concerning the position, course, and speed of other targets tracked by the station.

2. The designation and transmission by the shore station of courses which the piloted ship should follow in order to enter the fairway, and of the time for turning onto the next course, etc.

The use of shore station services does not relieve the Commanding Officer of the piloted ship, the navigator, and watch officer of the responsibility for navigational safety, for the determination of the position by any other available method, and for the observance of all other safety procedures in keeping with the situation at hand.

7. The Use of Continuous Wave Hyperbolic Radio Navigation Systems /217

The continuous wave hyperbolic radio navigation system (RSVT, Decca-Navigator, Omega, etc.) has one master and two or three slave shore stations. The slave stations relay the continuous electromagnetic oscillations emitted by the master station on different frequencies or during different time intervals. Installed aboard ship is a receiver-indicator (KPF-1, Pies-1, and others) consisting of a receiver, which receives the electromagnetic oscillations emitted by the shore stations, and phasemeters, each of which measures the phase difference of the oscillations received from the master station and from one of the slave stations. The phase difference is proportional to the difference in distances between the ship and the master station and the ship and slave station. The proportionality constant, i.e., the increment in the difference between distances, corresponding to the change in phase difference for one phase cycle (360°) is called the phase cycle equivalent.

Since the phase difference can be measured directly only within one phase cycle, the system is characterized by an ambiguity in readings, i.e., to a given phasemeter reading there corresponds not a single unique difference but several differences in ranges which differ by multiples of the phase cycle equivalent (depending on the frequencies of the master and slave stations, the range differences are from several hundred to several thousand meters), and their corresponding isolines

(lines along which the phase difference remains constant). The area between two adjacent isolines corresponding to an integral number of phase cycles, is called a lane. In order to resolve the ambiguity it is necessary to determine in which of these lanes the ship is located. This can be accomplished by two methods.

1. At the initial moment a tie-in is accomplished, i.e., one determines the ship's position by one of the most precise navigational methods. By plotting the observed point on the radio navigational chart with a hyperbolic grid, the phase differences corresponding to this point are obtained from the chart. The phasemeter counters are set at these readings. Thereafter the system should operate continuously. During brief interruptions in the reception of signals from the shore stations the /218 tie-in is restored from dead-reckoning data and, with prolonged interruptions, a new determination of the position should be made. In order to determine the position of the ship, phasemeter readings are taken, the hyperbolas which correspond to the reading of each phasemeter are located on the chart (if necessary interpolation is performed by eye or with the use of an interpolation ruler), and, at their point of intersection, the fix is plotted.

2. The master and slave stations operate alternately on different combinations of frequencies which correspond to the different phase cycle equivalents (lanes of different width). This makes it possible to obtain first, a rough measurement of the difference in ranges required to identify the number of the lane in which the ship is located and then a precise measurement which is needed in the determination of the position of the ship. Subsequently, one should proceed as in the first method. To avoid errors which will be difficult to detect later, carefully check the accuracy of the identification of lane numbers, utilizing for this purpose all the available methods for determining the position of the ship.

To evaluate the accuracy of determining the ship's position, use is made of Formulas (7.29) and (7.30) and Table 7.1 (the values d, Δ_U and θ are obtained from the radio navigational chart). The magnitude σ_U can be assumed to be equal to 0.05 of the phase cycle in daytime and 0.1 of the phase cycle at night.

8. The Use of Pulse-type and Pulse-Continuous Wave Hyperbolic Radio Navigation Systems

The master shore station of a pulse-type hyperbolic radio navigation system (Loran-A) emits 20 to 35 short radio pulses per second. The slave shore station emits each successive pulse after a strictly fixed interval of time following the pulse emission by the master

station. The interval of time between the reception of pulses from the master and slave stations is measured aboard ship by means of a special receiver indicator (KPI-3M, KPI-4, etc.). The time interval is proportional to the difference in distances from the ship to the master station and from the ship to slave station and the isoline, corresponding to this interval, is a hyperbola.

As in the continuous-wave radio navigation system (Lorac-C) one /219 measures the difference in phases of electromagnetic oscillations within the pulse envelope. Measurement of time intervals between the reception of pulses serves to identify the lane number and ensures a rough determination of the position of the ship.

Before determining the ship's position the receiver indicator should be switched on for 10-15 minutes for warm-up. Guided by the radio navigational chart with a grid of hyperbolas, one should select pairs of shore stations with radio navigation systems Loran-A and Loran-C, so that the distances to them would not exceed 900 miles, if possible, and the angle of intersection of the hyperbolas would be close to 90°. Record the codes of the chosen pairs. Set the controls of the receiver-indicator at the positions corresponding to the code of the first pair. Match the pulses observed on the screen with the pedestals and then with the measuring strobes. At the end of the servo system operation take the counter readings. If there are considerable variations in readings, one should take several readings in the extreme positions and calculate their average value. Repeat the same operations for the second pair of stations. After selecting the corrections (indicated on the chart) for the effect of the sky wave, use these corrections to adjust the indicator readings. Draw the sections of the hyperbolas corresponding to the results obtained (interpolate by eye or with the aid of an interpolation ruler). Bring the first position line up to the point of the last measurement (see Section 7.3, Subsection 6). At the point of intersection of the position lines mark the observed position of the ship (if there are more than two lines, mark the position at the center of the figure of errors).

To evaluate the accuracy of observation, use is made of Formulas (7.29) and (7.30) and Table 7.1 (the magnitudes of d, Δ_U, and θ are taken from the radio navigational chart). The rms errors of the pulse-type Loran-A and Loran-C radio navigational systems are: about 3 microseconds, in daytime and, with large variations in readings, about 10 microseconds at night.

9. The Use of Pulse-type Range Measuring Radio Navigation Systems

A pulse-type range measuring radio navigation system consists of a shipboard station, which emits short radio pulses, and two shore

stations, each of which transmits reply pulses at different frequencies. The time intervals between the transmission of pulses from the shipboard station and reception of reply pulses from each of the shore stations /220 are measured aboard ship. They are proportional to the distances to the shore stations. The isolines are circles. Charts with isoline grids are used in plotting the data of measurements. The isolines are expressed in the same units as the dials on the shipboard indicators (usually in kilometers).

It is sufficient to have two shore stations to determine the position of a ship; a tie-in is not required. The transmission of radio waves by the ship exposes the ship using the radio navigational system. A limited number of ships can use the system simultaneously (mutual interference impedes measurements). The systems operate on ultrashort wavelengths; the distances to the shore stations, for which measurement is possible, are determined from Formula (7.28). The rms error in determining the position of the ship is: 40 meters, for an angle of 90° between the bearing lines of the shore stations; and 100 meters, for an angle of 20° (160°).

10. The Use of Sonar Equipment

Shipboard sonars may be used to give warning when approaching dangers and to determine the position of the ship. In both cases, distances are measured between the ship and the areas on the sea bottom closest to the ship (between the ship and the first echo-signal). For identification of these areas bearings are also taken at the same time. On the chart, the measured distances are plotted from the "reflecting isobath," the marking of which can, in the first approximation, be considered to be equal to the depth of the transducer below the surface of the water.

Shipboard listening sonars are used for determining the position from bearings of artificial sources of sound (underwater radiators), whose locations should be well known and which should be plotted on the chart.

Sonar systems. Aboard ship the time is noted when sound signals are received from explosions produced at fixed time instants (according to a schedule) at specially designated points in the sea (focal points) whose coordinates are well known. For each focal point the propagation time of sound signals (the difference in time between the signal recep- /221 tion and explosion) is calculated and corrected to compensate for the deviation of the velocity of sound from the theoretical velocity. For plotting the data of measurements special charts are used on which isolines were drawn for each focal point, showing the propagation time of sound from the focal point.

Section 7.5. Checking the Navigational Plot. Characteristics of Navigation When Sailing Near Shores and in Narrow Channels

1. Checking the Navigational Plot

When sailing in narrow channels, near the shores and shoals, or when approaching them, and when the ship's position is in doubt, the officer of the watch shall strictly observe the precautionary measures prescribed by Ship Regulations of the USSR Navy. He should ascertain whether or not the accuracy with which the ship's position in known [Formula (7.25)] guarantees the safe execution of the mission; he shall check the accuracy of the navigational plot by watching the reference and dangerous bearings, distances, depths and navigational ranges (if the ship must pass through a narrow channel, approach the shore, or steam along the shore, the officer of the watch--before taking over the duty--shall note this on the chart; he shall record major data and keep in mind the most important items).

Reference bearings, distances, depths, and navigational ranges are obtained from the chart by measuring them from characteristic points which were plotted earlier and which indicate times of turning, traversing capes, etc. The difference between the measured values and the control values shows that the actual movement of the ship deviates from the projected preliminary plot.

Danger bearings, distances, depths, and ranges are used in warning when the ship approaches hazardous areas. They are selected so that even with the greatest possible error of measurement, the ship would have an open sea area between the dangerous isoline and the danger large enough to be able to avoid coming close to the danger. If the measured value is close to the critical value--and especially if it is equal to it--measures must be taken immediately to avoid the danger. /222

Fig. 7.15. Danger distance, depth, and bearing

It is best to select the reference and danger bearings and ranges so that their lines are almost parallel to the course line, i.e., the landmarks are dead ahead or astern. Mark the reference and danger distances to the landmarks that are located near the danger abeam the ship (Fig. 7.15).

2. Navigating on Ranges and Following Recommended Courses

When approaching a narrow channel one should get on the entrance range at the proper time so that there is enough room and time to check the accuracy of the executed manuever, to correct any possible errors, and to bring the ship exactly on the range.

In order to execute turns to place the ship on the next range or recommended course, use should be made of turning bearings and distances (Fig. 7.16) marked on the chart. In calculating a turning bearing or distance one should take into account not only the turning circle but /223
also the distance which the ship travels from the moment the command is given to the rudder to the moment the ship actually begins to turn.

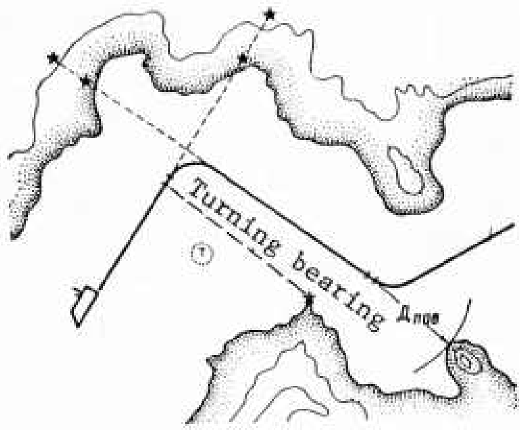


Fig. 7.16. Turning bearing and distance

In selecting a landmark for the turning bearing, it should be kept in mind that the moment a turn should begin will be determined with greater accuracy, the closer the landmark is to the ship, the smaller the angle formed by the turning bearing line and the range which the ship is about to follow, and the closer the landmark bearing line is to the beam of the ship on the original course (before the turn). It is more practical to mark the turning distances to those landmarks whose bearings form the smallest possible angles with the original course of the ship and which are as close as possible to the beam of the ship on her new course.

As soon as the range becomes visible, and after comparing its shape with descriptions presented in the sailing directions and in the manual Lights and Shapes, one should make certain that the range has been correctly identified; for this purpose one should take a bearing of the range and compare it with that given in the manual.

If one could not bring the ship exactly on the range, he should approach the range at an acute angle. An approach at a large angle usually does not accelerate but delays bringing the ship exactly on the range. A power-driven vessel should, if it is safe and possible, keep to that side of the fairway or channel which is on the starboard side of the vessel. Therefore, after bringing the ship exactly on the range, it is advisable, if the width of the fairway, the draft of the vessel, and navigation conditions permit, to veer slightly to the right and then steer parallel to the range but somewhat to the right of it, all the while checking the steering accuracy by making measurements and taking reference and danger bearings. /224

With wind and current causing the vessel to drift away from the range the prescribed course differs from the range bearing (axis of the fairway) by the expected value of the total drift which is always in that direction from which the wind blows (or from which the current flows). Careful observation makes it possible to determine the direction of the drift away from the range and to refine the initially prescribed course.

3. The Use of Radio Range Beacons

Radio range beacons emit the so-called interlocking signals of the telegraphic alphabet (A and N, D and U, or B and Zh). One of them (for example, A) is heard on one side of the equisignal zone while on the other side the opposite signal is heard (N in our example). When a ship is in the equisignal zone a continuous single-tone signal is heard.

To steer a ship in the equisignal zone of a radio beacon, the following basic characteristics must be obtained from the manual Electronic Navigational Aids: frequency (wavelength), identification signal, type of signals transmitted on both sides of the equisignal zone, and the operating schedule. After tuning (to the radio beacon frequency) a radio receiver of appropriate range or a radio direction finder operating in the omnidirectional reception mode, listen to the signals. On the basis of the signal received one should determine on which side of the equisignal zone the ship is located and set a course to bring the ship to the equisignal zone axis. When this signal ceases to be audible, steer a course coinciding with the range line direction. Repeat this procedure if the ship deviates from the axis of the equisignal zone,

i.e., when one of the interlocking signals from the radio beacon is audible again. The movement of the ship must be checked by using all available methods (by determining the position of the ship and by measuring reference and danger depths, distances, etc.). /225

4. Marking Navigational Dangers, Fairways and Canals with Floating Beacons

(Annex 1 and 2)

Floating beacons, i.e., lighted and unlighted buoys and spar buoys, are used to mark navigational dangers, fairways, mine-hazard areas, etc. Full information on marking systems in the Soviet Union is contained in Opisaniye sistem navigatsionnogo oborudovaniya v vodakh Soyusa SSR plavuchimi predosteregatel'nymi znakami (Description of Navigational Systems Using Floating Warning Beacons in the Waters of the USSR), published by the Main Administration of Navigation and Oceanography, Ministry of Defense, USSR. Information on marking systems used in foreign waters is presented in the appropriate sailing directions.

Buoys and spar buoys can serve only as warning devices, i.e., they can be used in giving an approximate idea about ship's position with respect to the navigational danger, fairway axis, etc. However, they may not serve as reference points for determining the position of a ship since they drift easily from their positions during storms, ice movements, and movements of passing ships. Upon detecting that a spar buoy or a buoy is not in its proper place or is missing, one should report this immediately to the nearest Hydrographic Service office.

The designated positions of buoys and spar buoys are indicated on large-scale charts. By reading the plot, the officer of the watch must know in advance when and along what direction he may encounter them. The absence of a spar buoy or a buoy at the time when its presence is expected may not be used as a basis for assuming that the ship is far away from any navigational danger. The sudden detection of a spar buoy or buoy that was not expected from the plot usually indicates that there is a serious dead reckoning error. In such a case measures must /226
be taken immediately to avoid its dangerous consequences.

In the system of marking navigational dangers throughout the world the north buoy (spar buoy) is placed south of the navigational danger and indicates "Keep me to the north." The south buoy (spar buoy) indicates "Keep me to the south;" the east buoy "Keep me to the east;" and the west buoy indicates "Keep me to the west."

Cross buoys (spar buoys) are placed at navigational dangers of small size and indicate: "I am lying over a navigational hazard. You may pass me on either side."

In the system of marking of canals and fairways, the right side buoys (spar buoys) are placed on the right side of the canal (fairway) relative to the path of the ship returning from the sea. They carry odd numbers, are black in color, have a white light, and indicate to the ship returning from the sea "Keep me to starboard." Buoys (spar buoys) of the left side carry even numbers, are red in color, have a red light, and indicate to the ship returning from the sea: "Keep me to port."

In the system of marking centers of fairways and recommended courses, midchannel spar buoys and buoys are used. They are placed along the axis of the fairway or along the recommended courses and indicate: "Proceed from buoy to buoy."

CHAPTER 8

CELESTIAL NAVIGATION

/227

Section 8.1. Preparing for Observations

1. Selecting Time and Celestial Bodies for Observations

To determine the position of a ship from the sun, the time for measuring two series of altitudes is when the azimuth of the sun changes by 50-60°, and the altitude is, if possible, no less than 10°.

In determining the position from stars and planets, evening observations begin at about the middle of civil twilight. In the morning they begin somewhat later than the beginning of nautical twilight. The selection of celestial bodies for observation is accomplished with the aid of a star globe (Fig. 8.1). One should first note thereon the apparent

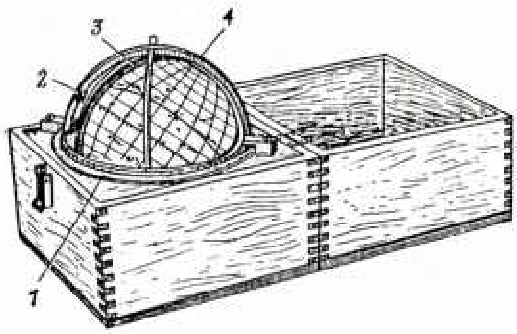


Fig. 8.1. Star globe

1 - horizontal ring; 2 - indicator; 3 - meridian ring of the observer; 4 - semicircular vertical ring

positions of the planets from the right ascensions and declinations, obtained from the Maritime Astronomical Yearbook (MAE). At the approximate time for the beginning of observations, determine (with an accuracy of up to 1°) the local sidereal time t_M^{Υ} (the local hour angle of the Point of Aries) (see Section 8.3, Subsection 2). By rotating ring 3 of the observer meridian adjust the globe so that the elevated pole (with the same designation as the latitude of the observer) is above the point (on the horizontal ring 1) which has the same designation as the pole above point N in northern latitudes and point S in southern latitudes while the axis of the globe forms, with the horizontal ring, an angle φ equal to the position latitude (the reading along the meridian ring at

the horizon should be $90° - \varphi$). By rotating the globe about its axis set a reading equal to the local sidereal time t_M^{Υ} on the celestial equator scale under the meridian ring of the observer.

Then select a combination of the brightest stars and planets so that their altitudes are approximately the same and lie within 10 to 70°, while the difference in azimuths of two celestial bodies is as close to 90° as possible, when determining the position from either four or two celestial bodies, or close to 120° when determining the position from three celestial bodies. By using the semicircular vertical rings 4 and indicator 2, obtain the azimuths and altitudes of the celestial bodies /228 selected and record them. Convert the azimuths from the quadrant to circular measure, bearing in mind that the azimuth in the circular measure is measured from point North N, from 0 to 360° clockwise, when viewing the globe from above. Calculate the compass bearings of the celestial bodies from Formula (7.8).

2. Determining Watch Corrections

Compare the watch with the chronometer (using the second beats of the chronometer, note the readings of the chronometer T_{ch} and of the clock T_w). Calculate the difference:

$$D = T_{ch} - T_w. \tag{8.1}$$

From the daily variation ω of the chronometer obtain its correction as of the time of comparison:

$$u_{ch} = u_{ch\,0} + \omega_n, \tag{8.2}$$

where n is the time interval, in days, between the last determination of the chronometer correction (on the basis of radio time signals) and the comparison time.

Calculate the watch correction as follows: /229

$$u = u_{ch} + D \tag{8.3}$$

Repeat this procedure after measuring altitudes and use the mean watch correction in the calculations.

3. Preparing the Sextant

Each observer must know (or record) the number of the sextant assigned to him and strictly observe the regulations for handling it

(hold the sextant only by the handle or by the frame; protect it from shocks, accumulation of dirt, dampness, and sharp changes in temperature; for an approximate setting of the index arm, press its legs together all the way and only then move it); keep a copy of the instrument corrections in the notebook containing forms for astronomical calculations. Focus the telescope beforehand and mark with a pencil your initials on the telescope. In order to prevent errors due to play in the index arm, the last rotation of the micrometer drum should always be made in the same direction in all measurements.

If possible, the sextant should be brought to the site 20-30 minutes before the observations begin so that its temperature would become equal to that of the outside air. Examine the sextant and make sure it is in good working order. Set the focus of the telescope and check it; check the perpendicularity of the index and horizon mirrors in the plane of the limb.

The index correction i can be determined from the sun, a star or, less accurately, from the visible horizon. Before making the determination, the index arm must be set at about 0°. If the index correction is determined from the sun, light filters must be used and arranged so that both images are neither too bright nor too dim (poorly distinguishable). By rotating the micrometer drum bring the limbs of the reflected and directly visible images of the sun into contact and record the sextant reading SR_1. Then bring other limbs of the images into contact and record the sextant reading SR_2. Calculate the mean sextant reading:

$$SR_m = 1/2(SR_1 + SR_2),$$

and the index correction:

$$i = 360° - SR_m. \qquad (8.4)$$

For checking purposes subtract the smaller reading from the larger one and divide the difference by four. Compare the semidiameter of the sun thus calculated with the semidiameter R given in the Maritime Astronomical Yearbook for the observation day, under the "Sun" column. If they differ by more than 0.2', repeat the index correction. /230

If the index correction is determined from a star, train the telescope on the star that is not too bright and match the reflected image with the directly visible image several times, record the sextant reading each time, and calculate its mean value SR_m. Compute the index correction from Formula (8.4).

If the index correction was not made before measuring the altitudes perform the correction immediately after the observations.

Section 8.2. Making Measurements and Recording Data

1. Measuring the Dip of the Visible Horizon

One should stand so that the level of the eye is the same as that when measuring the altitudes of celestial bodies and the line of the horizon is observed in two opposite directions. After arranging the inclinometer horizontally with the diaphragm toward the brighter part of the horizon, focus the images; by rotating the ring of the diaphragm, equalize the brightness of both parts of the horizon observed in the eyepiece. By rotating the grooved ring of the compensator on the eyepiece of the instrument, match the images of the horizon so that there would be neither light nor dark intervals between them, and take a reading. Turn around (through 180°) and turn the inclinometer through 180° about the axis of the telescope so that the diaphragm is again directed toward the brighter part of the horizon; repeat the matching of the horizon images and take a reading. Calculate the mean instrument reading and make a correction of the instrument by the amount selected from the instrument instruction book.

If the dip of the horizon was not measured before measuring the altitudes, perform measurements immediately after the observations.

2. Measuring the Altitudes of Celestial Bodies with a Marine Sextant /231

During morning and evening twilight, one should begin measurements of the celestial bodies located in the eastern part of the horizon (in the morning--in the brighter part, and in the evening--in the darker part). In the morning one should begin measuring the altitudes of stars with lesser brightness first, with the brightest stars and planets measured last. In the evening the altitudes of the brightest stars and planets are measured first and the stars of lesser brightness are measured last.

Before any observations of the sun are made, place a light filter or combination of several light filters in front of the index mirror so that the image of the sun would not blind the eye and would be sharply defined (likewise, place a filter in front of the horizon mirror when the sextant reading is about 0°).

To measure altitudes an observer shall:

- focus the telescope by eye and mount it on the sextant;

- set the azimuth circle of the compass at the compass bearing reading calculated with the aid of the star globe for the star or planet selected and set the index arm of the sextant at a reading

which is equal to the altitude of the celestial body and which was obtained from the star globe. After training the telescope on the horizon in the direction of the azimuth circle, find the celestial body selected for observations;

- if the bearing and altitude of the celestial body were not calculated beforehand, set the index arm at about 0° (when observing the sun place light filters in front of the index and horizon mirrors of the sextant); train the telescope on the celestial body selected; press together the legs of the index arm and, while lowering the telescope to the horizon, move the index arm, all the while maintaining the image of the celestial body in the field of view of the telescope until the line of the horizon appears there as well (in observing the sun when its directly visible image leaves the field of view of the telescope, remove the light filter from the horizon mirror); release the legs of the index arm and note and record the bearing of the celestial body;

- by turning the micrometer drum slightly, dip the image of the celestial body (limb of the sun) below the horizon if the altitude of the celestial body increases (before noon) or move it away from the water if the altitude of the celestial body decreases (after noon); give the "Stand-by" command to the second observer (Fig. 8.2);

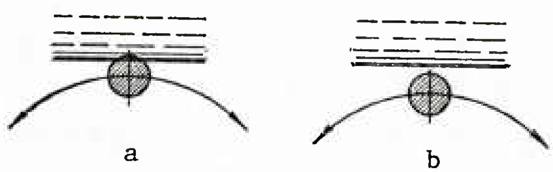


Fig. 8.2. Measuring the altitude of the lower limb of the sun (Stand-by):

a - before noon; b - after noon

- while slightly rocking the sextant about the telescope axis and simultaneously turning to the right and left so that the image of the celestial body (limb of the sun) is always at the center of the field of view, watch when it touches the line of the horizon; at that time give the command "Mark" following which rock the sextant one or two more times so as to be certain that the measurement is correct (if the altitude of the celestial body changes slowly, touching of the horizon line can be achieved by rotating the micrometer drum while rocking the sextant); /232

- take a reading from the limb (number of degrees) and from the micrometer drum of the sextant (number of minutes and tenths of minutes) and report this to the second observer;

- perform a series (3 to 5) of such measurements and check the accuracy of the entries made by the second observer; if the sun or moon were being observed, mark the altitude of which limb (upper or lower) was measured.

3. Recording Measurement Data

The second observer shall:

- on command "Stand-by", begin watching the second hand of the watch while counting the seconds to himself;

- on command "Mark", stop counting, record the number of seconds, then the number of hours and minutes and write the sextant reading reported by the first observer.

In measuring subsequent altitudes in this same series, the number of hours and minutes and the number of degrees in the sextant reading need not be recorded if they have not changed; however, make sure to check whether or not they were recorded correctly earlier.

Section 8.3. Calculations and Plotting of the Results Obtained /233

1. Preliminary Analysis of the Measurement Data

After completing measurements, calculate, for each series of altitudes, the middle point of the measurement time and the mean reading of the sextant and obtain from the chart or the dead reckoning tracer repeater, or calculate the position coordinates for the middle point in the measurement time for each series of altitudes when measuring sun's altitudes and the position coordinates for the middle point in the measurement time of the last series when measuring the altitudes of stars and planets. In determining the position from the sun, the coordinates for determining the second position line are obtained graphically or analytically on the basis of those used in determining the first position line (the data obtained during the time interval between measurements by other methods are not taken into account). Record all initial data such as the date, coordinates, height of the eye, course and speed of the ship, air temperature and pressure, names of the celestial bodies, middle points in the measurement times of the series, watch correction, mean sextant readings, and the sum of the index correction i and the instrument correction s of the sextant on the Sh-8, Sh-8a or the Sh-8b form.

2. Calculating the Hour Angle and Declination of a Celestial Body

First of all one calculates the approximate Greenwich time and determines the Greenwich data of the observation as follows:

$$\text{Approx. } T_{Gr} = \text{Approx. } T_c \pm N_W^O \tag{8.5}$$

where T_c is the time of observations according to the ship's watch;

N is the number of the time zone in which the watch was set (the eastern number is subtracted and the western added).

If it turns out that $T_c \pm N_W^O > 24$, when calculating with the aid of Formula (8.5), then 24 hours must be subtracted from the result obtained and the Greenwich date of the following day assumed. If in this calculation 24 hours had to be "borrowed" from the date, then the Greenwich date of the previous day should be used. /234

The precise Greenwich time of observations then is:

$$T_{Gr} = T + u + (12 \text{ hrs}). \tag{8.6}$$

where T is the middle point in the measurement time for the series;

u is the watch correction with respect to the Greenwich time. One adds 12 hours if the value of (T + u) differs by about 12 hours from the approximate Greenwich time calculated previously.

The selection from the Maritime Astronomical Yearbook of hour angles, declinations of celestial bodies and their interpolation corrections is made from the number of hours, minutes, and seconds of Greenwich time T_{Gr}. The western hour angle T_W and declination δ of the sun, moon, and planet are calculated from the formulas:

$$t_{Gr} = t_T + \Delta_1 t + \Delta_2 t; \tag{8.7}$$

$$t_W = t_{Gr} \pm \lambda_W^O; \tag{8.8}$$

$$\delta = \delta_T + \Delta\delta, \tag{8.9}$$

where t_T and δT are the Greenwich hour angle and declination taken from the daily table of the Maritime Astronomical Yearbook by using the whole number of hours of Greenwich time;

$\Delta_1 t$ is the first interpolation correction for the hour angle obtained from the basic interpolation table (corresponding to the whole number of minutes of Greenwich time) by using the number of seconds and the conventional symbol for the celestial body;

$\Delta_2 t$ and $\Delta\delta$ are the interpolation corrections, obtained from the same interpolation table (under the "Correction" column) by using the quasi-difference $\bar{\Delta}$ and difference Δ given in the daily tables.

The local sidereal time (the local hour angle of the Point of Aries) is calculated from the formulas:

$$t^{\Upsilon}_{Gr} = t^{\Upsilon}_{T} = \Delta_1 t; \tag{8.10}$$

$$t^{\Upsilon}_{M} = t^{\Upsilon}_{Gr} \pm \lambda^{0}_{W}. \tag{8.11}$$

The western sidereal angle is:

$$t_M = t^{\Upsilon}_{M} + t^*, \tag{8.12}$$

where t^* is the sidereal hour angle taken together with the declination of the star from the Table "Stars. Visible positions for the year 19..." in The Maritime Astronomical Yearbook.

If the western hour angle of the celestial body exceeds 180°, then one calculates the eastern hour angle as follows:

$$t_0 = 360° - t_W. \tag{8.13}$$

3. Calculating Altitudes and Azimuths of Celestial Bodies

Altitudes h_c and azimuths A_c are calculated with the aid of tables VAS-58, TVA-57, tables of logarithms, or values of the natural trigonometric functions by using the following arguments:

φ_c, the calculated latitude;

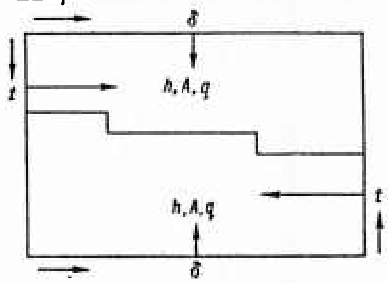
δ, the declination of the celestial body; and

t_M, the local hour angle (western, if it does not exceed 180°; or eastern).

In calculations using the VAS-58 tables, the table values for alti- /236
tude h_T, azimuth A_T, and auxiliary angle q are selected on the basis of

the arguments whose values are close to the given values; the differences Δ , Δδ and Δt between the given and tabular values of the arguments are caluclated and, from the interpolation tables, one selects the interpolation corrections Δh(ΔA) whose sum is added to the table value of the selected altitude (azimuth). The diagrams for using the tables are presented in Figs. 8.3 - 8.5.

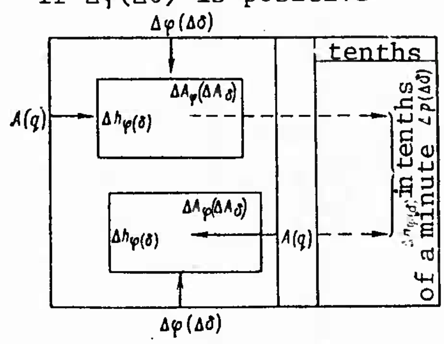
If ϕ and δ are the same



If ϕ and δ are different

Fig. 8.3. Diagram for using the basic VAS-58 tables

If $\Delta\phi(\Delta\delta)$ is positive



If $\Delta\phi(\Delta\delta)$ is negative

Fig. 8.4. Diagram for using the VAS-58 Interpolation Table 1

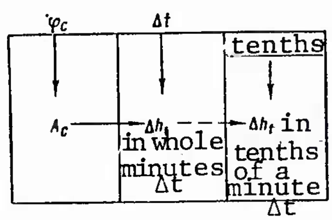


Fig. 8.5. Diagram for using the VAS-58 Interpolation Table 2

4. Correcting the Altitudes of Celestial Bodies

Corrections used in the adjustment of altitudes of celestial bodies are obtained from the back cover of the VAS-58 tables or from Tables 8-14 MT-63. First the measured and apparent altitudes of a celestial body are calculated:

$$\text{Meas. } h = sr + (i + s); \tag{8.14}$$

$$\text{Appar. } h = \text{Meas. } h + \Delta h_d, \tag{8.15}$$

where sr is the mean sextant reading;

(i + s) is the sum of the index correction and the sextant correction;

Δh_d is the correction for the dip of the visible horizon (it is equal to the value, with the sign reversed, of the dip measured by the inclinometer; if the dip of the visible horizon was not measured, the correction is obtained from the Table "Correction for dip" by using the height e of the observer's eye; if the altitudes of celestial bodies were measured by a sextant with an artificial horizon, then the correction is not taken into account).

The true altitude of a celestial body is calculated as follows:

- for the sun:

$$\text{True } h = \text{Appar. } h + \Delta h_{\rho + p} \pm R_{\odot}^{\odot} + \Delta h_t + \Delta h_B; \tag{8.16}$$

- for a star:

$$\text{True } h = \text{Appar. } h + \Delta h_\rho + \Delta h_t + \Delta h_B; \tag{8.17}$$

for a planet:

$$\text{True } h = \text{Appar. } h + \Delta h_\rho + \Delta h_p + \Delta h_t + \Delta h_B; \tag{8.18}$$

- for the moon:

$$\text{True } h = \text{Appar. } h + \Delta h_0 + \Delta h_t + \Delta h_B, \tag{8.19}$$

where $\Delta h_{\rho+p}$ is the correction for the refraction and parallax of the sun (obtained by using the apparent altitude);

R is the semidiameter of the visible disk of the sun (obtained

by using the date of observations; the correction is positive if the altitude of the lower limb was measured and negative if the altitude of the upper limb was measured; it is not taken into account if the measurements were made by a sextant with an artificial horizon); /238

Δh_t is the correction for the air temperature (obtained by using the apparent altitude of a celestial body and the temperature of the air);

Δh_B is the correction for the atmospheric pressure (obtained by using the apparent altitude of a celestial body and the atmospheric pressure);

Δh_ρ is the correction for refraction (obtained by using the apparent altitude);

Δh_p is the correction for the parallax (obtained by using the apparent altitude and value p given for each planet in the Maritime Astronomical Yearbook daily tables);

Δh_o is the total correction for the altitude of the lower (upper) limb of the moon.

If the hour angles, altitudes and azimuths of all celestial bodies are calculated on the basis of the same geographical coordinates φ and λ common to all of them and not on the basis of their own coordinates, then, in order to take into account the movement of the ship, corrections are introduced in the altitudes of all the celestial bodies--except the last one--for referring the altitudes to the zenith, i.e., to the position of the last measurement. For this purpose, following the calculation of the altitude and azimuth, it is necessary to determine--for each of the celestial bodies observed except the last one--the azimuth A_c (in the circular measure) and the difference A_c - ПY (path angle) or ПY - A_c if the current and drift are small (the true course of the ship may be used instead of ПY). Using this value and the speed of the ship one should select--from the Table Referring altitudes to the common zenith--the rate of change of the altitude per minute (the rate is designated by means of symbol Δh on the astronomical calculation forms). By multiplying it by the time interval ΔT, in minutes, between the mid-point in the time of measuring the altitudes of this celestial body and the mid-point in the time of measuring the altitudes of the last celestial body, obtain the correction Δh for referring to the common zenith (the sign of the correction factor is determined by the signs of Δh and Δt). Now calculate the referred altitude of the celestial body:

$$\text{Ref. } h = \text{True } h + \Delta h_z \tag{8.20}$$

The calculations end with the computation of the differences $(h-h_c)$ between the true and calculated altitudes (if the altitudes are referred

to a single zenith, then between the true and referred altitudes). These differences along with the calculated azimuths are the components of the astronomical position lines.

5. Plotting Position Lines and Calculating the Coordinates of a Fix /239

Lines of position are plotted on the course chart or on a plotting board on the back side of the astronomical calculation form, the center 0 of which is assumed to be the calculated position of the ship at the mid-point in the time of measuring the last series of altitudes (Fig. 8.6). Using the degree divisions on the frame of the plotting board, one should draw a straight line from this point, forming with the meridian line an angle equal to the calculated azimuth A_c of the celestial body (bearing of the illumination pole). Mark off the magnitude $(h - h_c)$ on this straight line, assuming that the side of one square on the plotting board is equal to 1' (one nautical mile). If the value $(h - h_c)$ is negative it is marked off in the opposite direction (opposite to the direction of the illumination pole). From point K obtained draw a straight line perpendicular to the azimuth line and obtain the required position line. Plot the remaining lines in a similar manner.

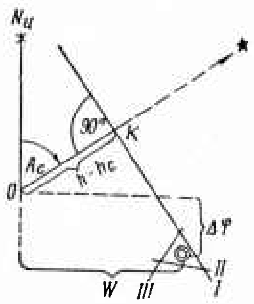


Fig. 8.6. Plotting position lines

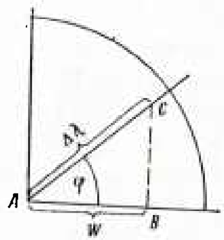


Fig. 8.7. Calculating the value of $\Delta\lambda$

If among other celestial bodies the altitude of Polaris was measured, then, after calculating its referred altitude from Formula (8.20) and adding the corrections obtained from the Tables "Latitude at the Altitude of Polaris" in the Maritime Astronomical Yearbook, one should determine the observed latitude φ_n and compute the difference $\varphi_n - \varphi_c$. If the difference is positive, then it is plotted toward the North from the center of the plotting board; if it is negative--toward the South. Through the point obtained, a position line is drawn perpendicular to the meridian of the calculated position (lines 0-180° on the plotting board).

The fix is marked at the point of intersection of the position lines drawn on the chart (board). If they do not intersect at one point, yet the requirement for the almost uniform distribution of the azimuths of the observed celestial bodies along the entire horizon (see Section 8.1, Subsection 1) is satisfied, then, in the triangle of errors, the fix is considered to be the point of intersection of the antimedians (straight lines symmetrical to the medians with respect to the bisecting lines). In a rectangle of errors the fix is the point of intersection of the lines connecting the midpoints of its opposite sides (one may mark these points by eye). If all the celestial bodies are located in one-half of the horizon, and the likely error in the dip of the visible horizon is commensurate with the random errors of measurement, then, to reduce the effect of systematic errors of measurement, more complex methods for finding the observed position should be used.

The plotting board gives the difference in latitudes $\Delta\varphi$ and departure w between the center of the plotting board and the observed point (as in plotting the differences (h-h), one square of the plotting board corresponds to 1'). We obtain the latitude φ by adding $\Delta\varphi$ to the calculated latitude used in determining the elements of the last position line (if the sign of $\Delta\varphi$ is opposite to that of the position latitude, then the latitude is assumed to be negative). In order to find the difference between the longitudes of the dead reckoning and observed positions a straight line AC must be drawn in the lower left corner of the plotting board (Fig. 8.7) to form an angle φ_c with the horizontal frame of the board; along the horizontal frame mark off the departure w and from the point B obtained draw a vertical line intersecting line AC. The length of AC in nautical miles (the number of squares on the plotting board) is numerically equal to the difference between the longitudes of the dead reckoning and observed positions. By adding it to the longitude of the dead reckoning position, we obtain the longitude λ of the observed point (if the sign of w is opposite to that of the longitude of the dead reckoning position, then the value $\Delta\lambda$ is considered to be negative.

In order to transfer the determined position from the plotting board to the chart, one should measure the bearing and distance (in terms of the number of squares on the plotting board, i.e., in nautical miles) from the center of the board to the point and, on the chart, plot the dead reckoning point whose coordinates were used in calculating h and A for the last position line (i.e., whose zenith was used as the reference point of altitudes of the celestial bodies). Then from the dead reckoning point one should plot the measured bearing and distance in the scale of the chart. /241

In evaluating the accuracy of astronomical observations based on the altitudes of two celestial bodies measured simultaneously, use is made of Formula (7.30) and Table 7.1 (the rms error m of the position

line is equal to the rms error of measuring the altitudes; under good observation conditions the rms error for the sun is 0.8 miles and for stars--1.2 miles); for observations based on the position lines measured at different times the rms error is obtained from Formula (7.36).

Section 8.4. Determining Compass Corrections

Several bearings (3 to 5) are taken of a celestial body whose altitude is as small as possible (one can see it through the telescope of a direction finder). During each measurement the time is noted. The local hour angle and declination of the celestial body are then calculated (see Section 8.3, Subsection 2) and its dead reckoning azimuth is determined (see Section 8.3, Subsection 3). The azimuth is converted into the circular measure and used as the true bearing of the celestial body. The compass correction is calculated from Formula (7.12).

Section 8.5. Calculating the Time of Rising and Setting of the Sun and Moon and of the Beginning and End of Twilight

The rising (setting) of the sun (moon) is the instant when the upper limb of the visible disk of this celestial body touches the line of the visible horizon. The beginning (end) of morning (evening) civil twilight is the instant when the true altitude of the center of the sun is equal to -6°. The beginning (end) of morning (evening) nautical twilight is the instant when the altitude of the center of the sun is equal to -12°.

By using the position latitude, one obtains, from the Maritime Astronomical Yearbook daily table, the table values T_t for the Greenwich time of the rising and setting of the sun and moon at the Greenwich /242
meridian and for the duration of civil t_c and nautical t_n twilight.

The local time for the rising (setting) of the sun (moon) is:

$$T_M = T_T + \Delta T_\varphi + \Delta T_\lambda + \Delta T_h. \qquad (8.21)$$

where ΔT and ΔT_λ are the corrections for the latitude and longitude obtained for the sun from Appendix 1 of the Maritime Astronomical Yearbook and for the moon from Appendix 2;

ΔT_h is the correction for the height of the eye and for the difference in the meteorological conditions from those given in the tables; it is calculated by using Table 20-E, MT-63.

The Greenwich and ship time for the rising (setting) of the sun (moon) at the meridian of the observer are:

$$T_{Gr} = T_M \pm \lambda_W^0 \qquad (8.22)$$

$$T_c = T_{GR} \pm N_W^0 \qquad (8.23)$$

where λ is the longitude of the position of the observer (it is converted from the degree measure into the time measure with the aid of Appendix 4, Maritime Astronomical Yearbook);

N is the number of the time zone according to which the watch on the ship is set.

The duration of the civil and nautical twilight at a given latitude is:

$$t_c = t_{ct} + \Delta t_{c\varphi}; \; t_n = t_{nt} + \Delta t_{n\varphi} \qquad (8.24)$$

where t_{ct} and t_{nt} are the table values for the duration of civil and nautical twilight;

$\Delta t_{c\varphi}$ and $\Delta t_{n\varphi}$ are the interpolation corrections, obtained from Appendix 1-a, Maritime Astronomical Yearbook.

The ship time for the beginning of the morning civil and nautical twilight is:

$$T_{bct} = T_B - t_c \text{ and } T_{bnt} = T_B - t_n \qquad (8.25)$$

where T_B is the ship time for sunrise.

The ship time for the end of evening civil and nautical twilight is:

$$T_{ect} = T_z + t_c; \; T_{ent} = T_z + t_n, \qquad (8.26)$$

where T_z is the ship time for sunset.

CHAPTER 9

FUNDAMENTALS OF SHIP MANEUVERING /243

Section 9.1. Methods for Solving Maneuvering Problems

1. Basic Designations

K - reference ship (ship with respect to which a maneuver is executed);

M - maneuvering ship.

The elements of the position of a maneuvering ship M, i.e., the quantities characterizing ship's position relative to the reference ship K are: the true bearing П of the maneuvering ship obtained from the reference ship or the relative bearing q_K of the reference ship; and the distance Д between the reference ship and the maneuvering ship. To change from one method of indicating the elements of the maneuvering ship position to another the following is used:

$$П = K_K + q_K \tag{9.1}$$

$$q_K = П - K_K, \tag{9.2}$$

where K_K is the true course of the ship K.

In using Formulas (9.1) and (9.2) the relative bearings of the starboard side are considered to be positive and those of the port side--negative. If the bearing $П_{MK}$ of the reference ship obtained from the maneuvering ship is known, then

$$П = П_{MK} \pm 180° + 2\psi \tag{9.3}$$

where ψ is the orthodromic correction (in northern latitudes, when $0 < П_{MK} < 180°$, it is positive and when $180° < П_{MK} < 360°$, it is negative; in the southern hemisphere its signs are reversed; when $\psi < 0.2°$ it can be assumed that $П = П_{MK} \pm 180°$).

2. Method of Relative Motion /244

The position triangle. The idea of the relative motion method (Fig. 9.1) lies in the fact that the bearings and distances characterizing the position of ship M with respect to ship K ($П_0$ and $Д_0$ is the

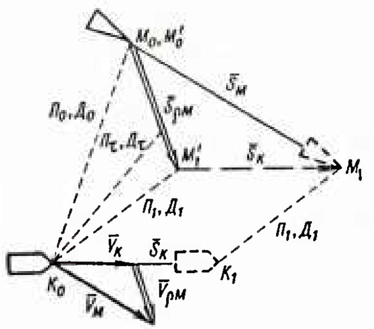
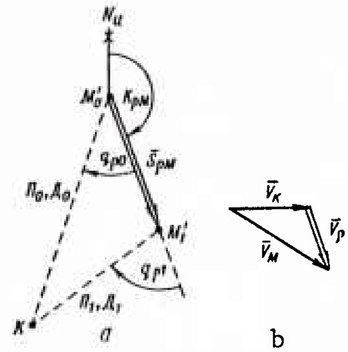


Fig. 9.1. Change in relative position of ships following constant courses at steady velocities



a   b

Fig. 9.2. Triangles
a - positions;
b - velocities

bearing and distance at the time when the maneuver begins; Π_t and $Д_t$--after an interval of time t; and Π_1 and $Д_1$--at the time the maneuver ends) are always plotted from the same point K representing the reference ship (in Fig. 9.1 it coincides with point K_0). The triangle $KM_0'M'$ thus constructed (Fig. 9.2) is the position triangle. Its vertices are:

- K - reference ship (the origin of a moving system of coordinates from which bearings and distances to another ship are measured);
- M_0' - initial relative position of the maneuvering ship;
- M_1' - final relative position of the maneuvering ship.

The sides of the position triangle are:

- $Д_0$ - initial distance between ships;
- $Д_1$ - final distance;
- $\bar{S}_{\rho M}$ - vector of relative motion of ship M with respect to ship K (its origin is point M_1')

The relative course $K_{\rho M}$ is the angle between the line of the true meridian and vector $\bar{S}_{\rho M}$. The relative bearing q_ρ is the angle between vector $\bar{S}_{\rho M}$ and the line of bearing ($q_{\rho 0}$ is the initial relative bearing and $q_{\rho 1}$ is the final relative bearing). The relative travel S_ρ is the

modulus of vector $\bar{S}_{\rho M}$.

<u>The velocity triangle</u> has the following sides (see Fig. 9.2; in Fig. 9.1 the velocity triangle is constructed at point K_0):

$\bar{V}_K$ - velocity vector of the reference ship;

$\bar{V}_M$ - velocity vector of the maneuvering ship;

$\bar{V}_{\rho M}$ - relative velocity vector.

The relative velocity V_ρ is the modulus of vector $\bar{V}_{\rho M}$.

<u>The movement triangle</u> (triangle $M_0 M_1 M_1'$ in Fig. 9.1) is similar to the velocity triangle; its sides are: /246

$\bar{S}_K$ - vector of absolute motion of the reference ship;

$\bar{S}_M$ - vector of absolute motion of the maneuvering ship;

$\bar{S}_{\rho M}$ - vector of relative motion of the maneuvering ship with respect to the reference ship.

<u>Basic relationships</u>.

- the relative velocity vector $\bar{V}_{\rho M}$ is parallel to the relative motion vector $\bar{S}_{\rho M}$ and is oriented in the same direction;

- the sides of the velocity and movement triangles are related as follows:

$$\bar{V}_M = \bar{V}_K + \bar{V}_{\rho M} \text{ and } \bar{S}_M = \bar{S}_K + \bar{S}_{\rho M}; \qquad (9.4)$$

- the relationship between the relative motion, relative velocity, and maneuver time t is:

$$S_\rho = V_\rho t. \qquad (9.5)$$

<u>The inverse construction of the position triangle</u> (Fig. 9.3) is used in determining the elements of motion of targets and in solving maneuvering problems at combat information centers (CIC). The origin of the movable system of coordinates is the maneuvering ship M. Bearings Π_{MK} of the reference ship and distances between the maneuvering ship and the reference ship are plotted from point M; K_0' and K_1' are the initial and final relative positions of the reference ship.

The vector $\bar{S}_{\rho K}$ of the relative motion of the reference ship with respect to the maneuvering ship has as its origin point K'_0 and as its end point K'_1. The basic relationships are:

$$\bar{V}_{\rho K} \parallel \bar{S}_{\rho K}; \quad \bar{V}_K = \bar{V}_M + \bar{V}_{\rho K}; \quad \bar{S}_K = \bar{S}_M + \bar{S}_{\rho K}; \tag{9.6}$$

$$S_\rho = V_\rho t; \quad \bar{S}_{\rho K} = -\bar{S}_{\rho M}; \quad \bar{V}_{\rho K} = -\bar{V}_{\rho M}. \tag{9.7}$$

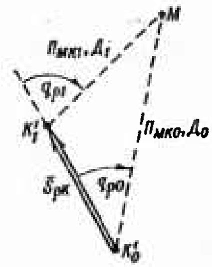


Fig. 9.3. Inverse construction of the position triangle

A <u>maneuvering board</u> (Fig. 9.4) is used to solve position and velocity triangles. The basic rules are:

- <u>bearings and ranges</u>: always plot the initial $П_0$ and $Д_0$ and final /248 $П_1$ and $Д_1$ (in the inverse construction of the position triangle $П_{MK0}$ and $Д_0$ and $П_{MK1}$ and $Д_1$) and the velocity vectors $\bar{V}_K$ and $\bar{V}_M$ of the reference ship and maneuvering ship, respectively, from the maneuvering board center representing the reference ship (in the inverse construction of the position triangle the center of the maneuvering board represents the maneuvering ship M);

- <u>range scale</u>: one division on the maneuvering board equals 10 cable lengths; <u>velocity scale</u>: one division on the maneuvering board equals 1 cable length/min (if necessary, the range scale may be increased or decreased by a factor of two, five, or ten);

- relative positions of the maneuvering ship: the initial M'_0 and final M'_1 positions are designated by circles and the ends of vectors by arrows (in the inverse construction of the position triangle these are the relative positions K'_0 and K'_1 of the reference ship);

- the origin of vector $\bar{S}_{\rho M}$ is the point M'_0 and its end point is M'_1 (in the inverse construction of the position triangle, the origin of the

vector $\bar{S}_{\rho K}$ is the point K_0' and its end point is K_1');

- the vector $\bar{V}_{\rho M}$ in the velocity triangle is parallel to vector $\bar{S}_{\rho M}$ in the position triangle and is oriented in the same direction (in the inverse construction of the position triangle the vector $\bar{V}_{\rho K}$ in the velocity triangle is parallel to vector $\bar{S}_{\rho K}$ in the position triangle);

- vector $\bar{V}_{\rho M}$ has as its origin the end of vector $\bar{V}_K$ and as its end point the end of vector $\bar{V}_M$ (in the inverse construction of the position triangle, the vector $\bar{V}_{\rho K}$ has as its origin the end of vector $\bar{V}_M$ and as its end point--the end of vector $\bar{V}_K$), i.e., the vectorial equality $\bar{V}_M = \bar{V}_K + \bar{V}_{\rho M}$ must be satisfied (in the inverse construction of the position triangle $\bar{V}_K = \bar{V}_M + \bar{V}\rho_K$).

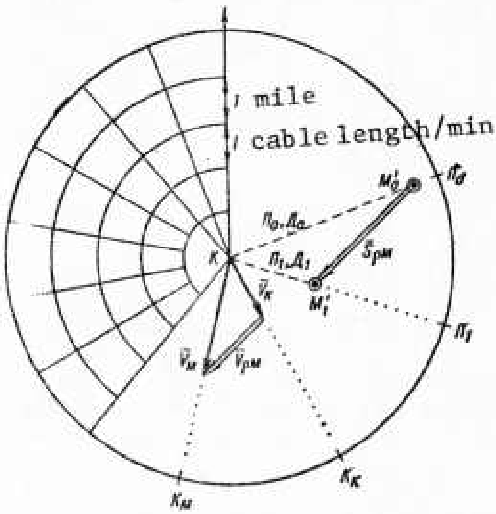


Fig. 9.4. Maneuvering board

3. Solving Maneuvering Problems on a Chart

In order to make an engagement plot when solving maneuvering problems on a chart or plotting board, the above rules must be followed. The position and velocity triangles are usually constructed at point K_0 (see Fig. 9.1). To construct the movement triangle, the course line of the maneuvering ship is drawn from point M_0 parallel to vector V_M; from point M_1' an auxiliary line is drawn parallel to the course line of the reference ship; the point of intersection of these lines yields /249

the position M_1 of the maneuvering ship at the end of the maneuver.

4. Basic Maneuvering Elements

OVIR - overall change in distance (the rate of change in distance between ships);

VIR - change in distance;

OBP - total lateral movement (auxiliary quantity used in the calculation of VIP);

VIP - change in bearing (the rate of change in bearing).

OVIR and OBP are calculated from the following formulas:

$$OVIR = VIR_K + VIR_M \tag{9.8}$$

$$OBP = BP_K + BP_M \tag{9.9}$$

If VIR_K, VIR_M, and BP_M are expressed in the same units as the velocities of the ships, then:

$$VIR_K = -V_K \cos q_k; \quad VIR_M = -V_M \cos q_M; \tag{9.10}$$

$$BP_K = V_K \sin q_K; \quad BP_M = V_M \sin q_M. \tag{9.11}$$

If the mangitudes of VIR and BP are expressed in cable lengths/min and the velocities of ships are in knots, then:

$$VIR_K = \frac{1}{6} V_K \cos q_K; \quad VIR_M = -\frac{1}{6} V_M \cos q_M; \tag{9.12}$$

$$BP_K = \frac{1}{6} V_K \sin q_K; \quad BP_M = \frac{1}{6} V_M \sin q_M. \tag{9.13}$$

The values OVIR and OBP in cable lengths/min in terms of the relative velocity in knots and relative bearing are:

$$OVIR = -\frac{1}{6} V_\rho \cos q_\rho; \tag{9.14}$$

$$OBP = \frac{1}{6} V_\rho \sin q_\rho. \tag{9.15}$$

Rules for signs (Fig. 9.5). For acute angles on the bow of ship M (ship K) the magntidue of VIR_M (VIR_K) is negative; for angles on the stern--the magnitude is positive. For relative bearings of ship M (ship K) to starboard, the magnitude of $BP_M(BP_K)$ is positive; to port--negative. VIP has the same sign as OBP. /250

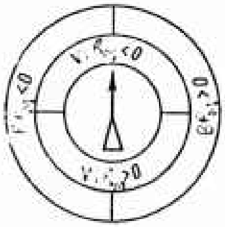


Fig. 9.5. Rules for signs

The magnitude of VIP in degrees/min is:

$$VIP = 57.3° \frac{OBP}{Д} \tag{9.16}$$

where OBP is in cable lengths/min and $Д$ is in cable lengths.

Expressions for the final distance and bearing in terms of the initial distance and bearing are:

$$Д_1 = Д_0 + OVIR \cdot t \tag{9.17}$$

$$П_1 = П_0 + VIP \cdot t \tag{9.18}$$

where t is the maneuvering time.

Formulas (9.17) and (9.18) are approximate. Errors arising from their use will increase with a greater change in bearing between ships during the maneuvering time. Tables 33a and 33b in MT-63 are used to simplify calculations by means of Formulas (9.10) - (9.16).

Geometric meaning of the basic maneuvering elements: VIR_M (VIR_K) is the magnitude of the projection of the velocity vector of ship M (ship K) on the line of bearing between the ships; $BP_M(BP_K)$ is the magnitude of the projection of the velocity vector of ship M or ship K on the line perpendicular to the bearing line; OVIR and OBP are the projections of the relative velocity vector on those same lines; OVIR is positive if the distance between the ships increases and negative if the distance decreases; OBP is positive if the bearing between the /251

ships changes clockwise and negative if the bearing changes counter-clockwise.

Section 9.2. Changing the Position of the Maneuvering Ship Relative to the Reference Ship

Given: K_K and V_K; Π_0 (q_{K0}) and $Д_0$; Π_1 (q_{K1}) and $Д_1$; V_{M3}

Find: K_M and t.

On a maneuvering board (Fig. 9.6) begin the solution of the problem with the construction of a position triangle. By assuming that the object of the maneuver K is represented by the center of the board, mark off a distance $Д_0$ from the center along the initial bearing line Π_0 and obtain the initial relative position M_0 of the maneuvering ship. From the given bearing Π_1 and distance $Д_1$ plot the given relative position M_1'. Find the relative movement vector $\bar{S}_{\rho M}$ with its origin at point M_0' and its end point at M_1'.

Solve the velocity triangle: from the center of the board mark off the velocity vector $\bar{V}_K$ of the reference ship and from its end point draw a straight line (parallel to the vector $\bar{S}_{\rho M}$ and in the same direction) intersecting the maneuvering board circle corresponding to velocity V_{M3} of the maneuvering ship; mark the point of intersection as the end point of vector $\bar{V}_M$ (its origin is at the center of the board) and vector $\bar{V}_{\rho M}$ (its origin is at the end point of vector $\bar{V}_K$). Take, from the board, the course K_M that the maneuvering ship should steer to execute the maneuver (the direction of vector $\bar{V}_M$).

Measure the relative movement S_ρ (the length of vector $\bar{S}_{\rho M}$) and relative velocity $\bar{V}_\rho$ (the length of vector $\bar{V}_{\rho M}$) and compute the maneuvering time $t = S_\rho/V_\rho$.

On a chart (Fig. 9.7) the problem is solved exactly as on the maneuvering board. Here the initial position K_0 of the reference ship plays the role of the center of the board. In addition, one constructs the movement triangle. One should plot the initial position K_0 of the reference ship and M_0 of the maneuvering ship; from point K_0 mark off the given bearing Π_1 and distance $Д_1$; plot the given relative position M_1' of the maneuvering ship (the initial relative position M_0' coincides /252

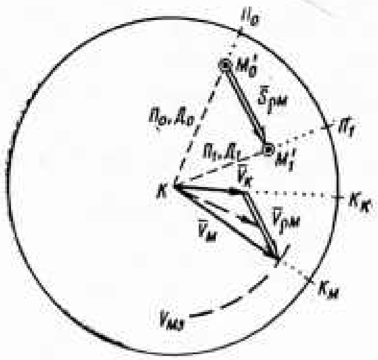


Fig. 9.6. Changing the position in the shortest time interval (on a maneuvering board)

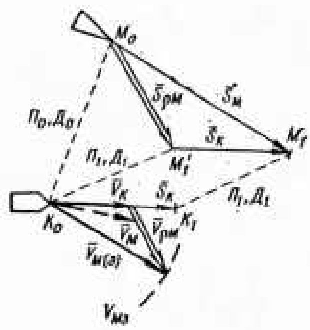


Fig. 9.7. Changing the position in the shortest time interval (on a chart)

with point M_0). Find the relative movement vector $\bar{S}_{\rho M}$ with its origin at point M_0 (coinciding with point M_0') and its end point at M_1'.

Construct the velocity triangle: from point K_0 mark off the velocity vector $\bar{V}_K$ of the reference ship and, from that same point, draw a circle with a radius equal to the velocity V_{M3} of the maneuvering ship. From the end of vector $\bar{V}_K$, parallel to vector $\bar{S}_{\rho M}$ and in the same direction, draw a straight line intersecting this circle. Mark the point obtained as the end of velocity vector $\bar{V}_{M(3)}$ of the maneuvering ship (its origin is point K_0). From the chart take the course K_M that the maneuvering ship should steer to execute the maneuver (the direction /253 of vector $\bar{V}_M$).

Construct the movement triangle: from point M_0, parallel to vector

$\bar{V}_M$, draw the course line of the maneuvering ship; from point M_1' draw an auxiliary straight line parallel to the course line of the reference ship. At their point of intersection mark the position M_1 of the maneuvering ship at the end of the maneuver.

From point M_1 draw a straight line with the direction opposite to the given bearing Π_1 at the end of the maneuver. At the point of intersection of this line with the course line of the reference ship mark the position K_1 of the reference ship at the end of the maneuver. (Check: the distance from point K_1 to point M_1 must be equal to the given distance Д_1 at the time the maneuver ends.) Measure the absolute motion S_K of the reference ship (distance K_0K_1) and S_M of the maneuvering ship (distance M_0M_1) and calculate the time of the maneuver $t = S_M/V_M = S_K/V_K$ (the time is calculated twice in order to check the solution of the problem).

<u>Selecting speeds for executing a maneuver</u>. If V_{M3} is the flank speed of the maneuvering ship and if the maneuvering time does not necessarily have to be minimal, then, in order to change station with respect to the reference ship, either of the vectors $\bar{V}_M$ may be selected, the origin of which is at the center of the maneuvering board (at point K_0 when solving the problem on a chart) and the end point on the straight line drawn from the end of vector $\bar{V}_K$ parallel to the given vector of /254
the relative motion $\bar{S}_{\rho M}$ and in the same direction (one of the possible solutions of $\bar{V}_M$, for $V_M < V_{M3}$, is shown in Figs. 9.6 and 9.7 with dashed lines). During station changes in a formation or order when vector $\bar{S}_{\rho M}$ forms with vector $\bar{V}_K$ an angle greater than 90° the execution of a maneuver at a lesser speed can become more practical since it would reduce both the turning angle of the maneuvering ship away from the formation course and her velocity relative to other ships. It would facilitate the execution of the maneuver and sometimes shorten the overall maneuver time because of the reduction in the time required for turning.

2. Changing Position in a Given Time Interval

Given: K_K and V_K; Π_0 (q_{K0}) and Д_0; Π_1 (q_{K1}) and Д_1, and t.

Find: K_M and V_M.

On a maneuvering board (Fig. 9.8). Construct the position triangle: along Π_0 and $Д_0$ mark the initial relative position M'_0 of the maneuvering ship; along Π_0 and $Д_0$ mark the given relative position M'_1. Find the relative movement vector $\bar{S}_{\rho M}$ (its origin is point M'_0 and its end point M'_1) and calculate the relative velocity $V_\rho = S_\rho/t$.

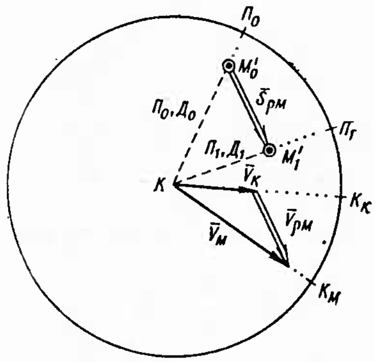


Fig. 9.8. Changing the position in a given time interval (on a maneuvering board)

Construct the velocity triangle: from the end of the velocity vector V_K of the reference ship, parallel to vector $\bar{S}_{\rho M}$ and in the same direction, draw vector $\bar{V}_{\rho M}$ (its length is equal to the computed value of V_ρ); mark the point obtained as the end of vector $\bar{V}_M$ (its origin is at the center of the board). From the diagram note the direction of vector $\bar{V}_M$ (course K_M of the maneuvering ship) and measure its length (speed V_M at which the maneuvering ship must proceed).

On a chart the first solution variant is similar to the solution on a maneuvering board. In addition to the above, a movement triangle is constructed (the course line of the maneuvering ship is drawn from point M_0 parallel to vector $\bar{V}_M$; the auxiliary line is drawn from point M'_1 parallel to the course line of the reference ship; the position M_1 of the maneuvering ship at the time of completion of the maneuver is marked at their point of intersection). One also plots position K_1 of the reference ship at the time of completion of the maneuver by drawing (from point M_1) a line, whose direction is opposite to that of the given /255

bearing line $П_1$, to intersect the course line of the reference ship.

The second solution variant (Fig. 9.9). After calculating the distance $S_K = V_K t$ which the reference ship will travel during time t, plot point K_1, i.e., the position where she will be located at the time when the maneuver ends. From this point plot the given bearing $П_1$ and distance $Д_1$ and mark the point M_1 where the maneuvering ship must be /256
located at this time. Draw the course line M_0M_1 of the maneuvering ship and measure its bearing (ship's course K_M) and length S_M and calculate the speed at which the maneuver must be executed $V_M = S_M/t$.

3. Maintaining the Position Given by the Relative Bearing of the Reference Ship and Distance During Changes in Her Course

Given: K_{K1} (before turning), K_{K2} (after turning), V_K, q_{K3}, $Д_3$ and V_M.

Find: K_M and t.

The problem is solved on a maneuvering board and on a chart as a special case of changing the position in the shortest time interval. The initial relative position M'_0 of the maneuvering ship is plotted on the basis of course K_{K1} of the reference ship before the turn and relative bearing q_{K3} at which the maneuvering ship must be maintained. The relative position M'_1 at the time the maneuver ends is based on the course K_{K2} of the reference ship after the turn and her given relative bearing q_{K3} which the maneuvering ship should have upon completion of the maneuver. Now one should find the relative motion vector $\bar{S}_{\rho M}$

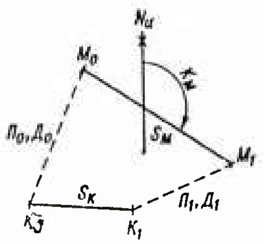


Fig. 9.9. Changing the position in a given time interval (on a chart; the second solution variant)

(its origin is point M_0' and its end point is M_1'). The construction of the velocity triangle and of the movement triangle (when solving the problem on a chart) as well as the calculation of the maneuvering time are performed in the same way as when solving the problem of changing the position in the shortest time interval (see Section 9.2, Subsection 1).

4. Changing Station Relative to the Reference Ship When $V_M < V_K$. The Accessible Position Sector

For $V_M < V_K$ the problem of changing stations either may not have a solution (the maneuvering ship is not in a position to assume the station assigned) or it may have two solutions (the first solution, in which the relative velocity V_ρ is high corresponds to the minimum maneuvering time and the second--to the maximum maneuvering time).

For $V_M < V_K$ the maneuvering ship may take any relative station located inside the accessible position sector. On a maneuvering board the construction is as follows (Fig. 9.10): from the end of vector $\bar{V}_K$ draw the lines tangent to the circle of the board the radius of which, in the scale selected, is equal to the speed V_M and find the relative velocity vectors $\bar{V}_{\rho M1}$ and $\bar{V}_{\rho M2}$ corresponding to the maximum bearings within which relative motion is permissible (the origin of each vector is the end of vector $\bar{V}_K$ and the end point of each vector is the point of tangency). Find the velocity vectors $\bar{V}_{M1}$ and $\bar{V}_{M2}$ of the maneuvering ship (the origin is at the center of the diagram and the end point--the point of tangency). From the initial relative position M_0' of the maneuvering ship, parallel to vectors $\bar{V}_{\rho M1}$ and $\bar{V}_{\rho M2}$, draw the boundaries of the accessible position sector (maximum permissible bearings of the relative motion vector). Similarly to vectors $\bar{V}_{\rho M1}$ and $\bar{V}_{\rho M2}$, these boundaries form, with the direction opposite to the direction of vector $\bar{V}_K$, angles equal to the critical course angle Q of the reference ship. /257 /258

5. Approaching the Reference Ship at the Shortest Distance

The shortest distance at which a maneuvering ship can approach the reference ship when $V_M < V_K$ and $Q_{K0} > Q$, is:

$$Д k_p = Д_0 \sin(q_{k0} - Q) \tag{9.19}$$

where Q is the critical course angle of the reference ship.

On a maneuvering board (Fig. 9.10) the solution of the problem should begin with the construction of the maximum velocity triangles and drawing of the boundaries of the accessible position sector. To that position which passes closer to the center of the board, drop a perpendicular from the center and mark the relative position M_1' of the maneuvering ship at the end of the maneuver. From the maneuvering board take course K_{M1} of the maneuvering ship (the direction of velocity vector $\bar{V}_{M1}$ at which the relative motion will be along line $M_0'M_1'$) and measure the length of the relative motion vector S_ρ and the shortest distance $Д_{KP}$ (the length of the perpendicular KM_1'). The maneuvering time is $t = S_\rho/V_\rho$.

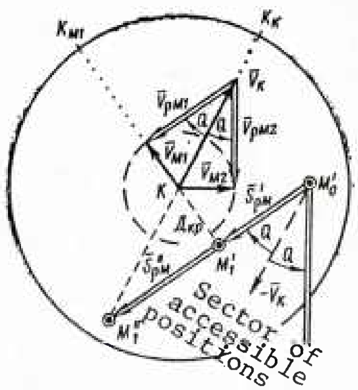


Fig. 9.10. Sector of accessible positions; approaching the reference ship at $Д_{KP}$ and crossing the course of the reference ship at the minimum distance astern

On a chart (Fig. 9.11) the problem is solved in a similar manner (the maximum velocity triangles are constructed at point K_0). In addition, a movement triangle $M_0M_1'M_1$ is constructed (see Section 9.1, Subsection 3) and the maneuvering time is calculated from the formula $t = S_K/V_K = S_M/V_M$.

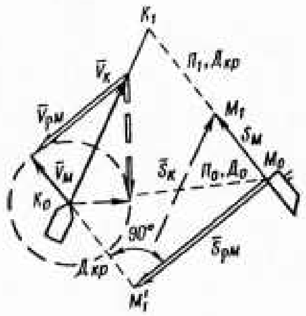


Fig. 9.11. Approaching the reference ship at the shortest distance (on a chart)

6. Crossing the Course of the Reference Ship at a Maximum Distance Ahead or Minimum Distance Astern

The maximum distance at which a maneuvering ship can cross the course ahead of the reference ship when $V_M < V_K$ (or the minimum distance at which crossing of the course astern of the reference ship is /259
possible) is:

$$Д_1 = \frac{\sin|q_{K0} - Q|}{\sin Q} Д_0. \tag{9.20}$$

When the difference (q_{K0} - Q) is positive the course of the reference ship is crossed astern of that ship and when the difference is negative it is crossed ahead of the ship. The relative position M_1'' (Fig. 9.10) of the maneuvering ship at the end of the maneuver is at the point of intersection of the boundary of the accessible position sector with the reference ship course line. The velocity vector $\bar{V}_M$ and course K_M of the maneuvering ship must correspond to the relative movement along the boundary of the accessible position sector (see Section 9.2, Subsection 4).

Section 9.3. Approaching the Reference Ship

1. Close Approach to the Reference Ship

The problem dealing with a close approach to the reference ship is solved on a chart or on a maneuvering board as a special case of the problem of changing station in the shortest time interval (see Section

9.2, Subsection 1). In constructing the position triangle, the given relative position of the maneuvering ship M_1' coincides with point K representing the reference ship, and the relative movement line coincides with the line of the initial bearing between the ships. In making a close approach the bearing between the ships, the relative bearings of the reference and maneuvering ships, and the overall rate of change in distance between the ships remain constant during the entire period of the maneuver. The relative course angle q_M, to which the reference ship must be brought by the maneuvering vessel for a close approach, is found from the equation: /260

$$\sin q_M = \frac{V_K}{V_M} \sin q_K. \tag{9.21}$$

For $V_M < V_K$, the possibility of a close approach is determined by comparing the initial relative course angle q_{K0} of the reference ship with the critical course angle Q. If $q_{K0} \ll Q$, a close approach is possible; if $q_{K0} > Q$, it is impossible. The critical course angle is found from the equation:

$$\sin Q = \frac{V_M}{V_K} \tag{9.22}$$

2. Approaching the Reference Ship at a Given Distance and Constant Bearing (the Close Approach Course)

This maneuver is a special case of changing station in the shortest time interval. In constructing the position triangle, the given relative position M_1' of the maneuvering ship is marked on the initial bearing line at the given distance $Д_1$ from the center of the maneuvering board (point K). The relative course angle q_M of the maneuvering ship, to which the reference ship must be brought, can be calculated from Formula (9.21). When $V_M < V_K$ a solution of the problem is possible if $q_{K0} < Q$.

3. Approaching the Reference Ship at a Given Distance in the Shortest Time Interval

The course of the maneuvering ship must coincide with the close approach course line containing the auxiliary point that moves behind the reference ship at a distance equal to

$$x = (V_K/V_M)Д_3 \qquad (9.23)$$

At the time of completion of the maneuver the reference ship must be positioned directly ahead and close to the bow of the maneuvering ship.

On a maneuvering board (Fig. 9.12): along $П_0$ and $Д_0$ mark the initial relative position of the maneuvering ship. Calculate the value of x from Formula (9.23) and, after plotting it from the center of the board in the direction opposite to the direction of $\bar{V}_K$, plot auxiliary point Φ'. At the point of intersection of line $M_0'\Phi'$ with the circle of the maneuvering board, corresponding to the given distance $Д_3$, plot the relative position M_1' of the maneuvering ship at the end of the maneuver (if $V_M < V_K$ then, from the two points of intersection, select the point which is closer to point M_0'). Find the relative movement vector $\bar{S}_{\rho M}$ (its origin is point M_0' and its end point is M_1') and construct the velocity triangle. From the end of vector $\bar{V}_K$ parallel to vector $\bar{S}_{\rho M}$ and in the same direction draw a line intersecting the maneuvering board circle, corresponding to velocity V_M of the maneuvering ship. Mark /262 the point obtained as the end of vector $\bar{V}_{\rho M}$ (its origin is the end of vector $\bar{V}_K$) and of vector $\bar{V}_M$ (its origin is at the center of the board). The end of vector $\bar{V}_M$, the center of the board, and point M_1' must all lie on the same straight line. The maneuver time is $t = S_\rho/V_\rho$.

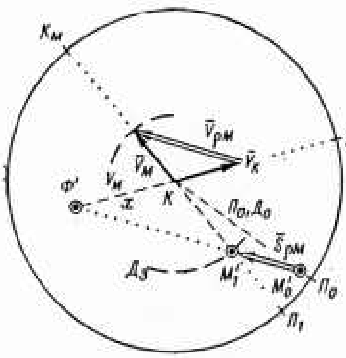


Fig. 9.12. Approaching the reference ship at a given distance in the shortest time interval (on a maneuvering board)

On a chart (Fig. 9.13) the problem is solved in the similar manner. The position and velocity triangles are constructed at point K_0 (coinciding with this point are the vertex K of the position triangle, the origin of vector $\bar{V}_K$, and the center of the circle corresponding to velocity V_M of the maneuvering ship). In addition, the movement triangle $M_0M'_1M_1$ is constructed (see Section 9.1, Subsection 3). The maneuvering time is $t = S_M/V_M = S_K/V_K$.

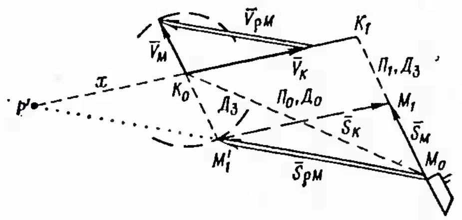


Fig. 9.13. Approaching the reference ship at a given distance in the shortest time interval (on a chart; for $V_M < V_K$)

The feasibility of approaching the reference ship at a given distance when $V_M < V_K$ is determined by comparing the initial relative bearing q_{K0} of the reference ship with the maximum relative bearing $Q_{\Pi p}$. If $Q_K < Q_{\Pi p}$, an approach at a given distance is possible; if $q_{K0} > Q_{\Pi p}$, it is impossible. The maximum relative bearing is:

$$Q_{\Pi p} = Q + \Delta Q, \tag{9.24}$$

where Q is the critical bearing and ΔQ is the critical bearing correction;

$$\sin \Delta Q = \frac{Д_з}{Д_0}. \tag{9.25}$$

Values of Q and ΔQ are presented in Table 9.1 (set $R = Д_3$ when using the Table). /263

Table 9.1
Critical bearing Q of the reference ship and correction ΔQ for calculating the maximum relative bearing

$\frac{V_M}{V_K}$ or $\frac{R}{Д_0}$	Q or ΔQ, degrees	$\frac{V_M}{V_K}$ or $\frac{R}{Д_0}$	Q or ΔQ, degrees
0.00	0	0.50	30.0
0.05	2.9	0.55	33.4
0.10	5.7	0.60	36.9
0.15	8.6	0.65	40.5
0.20	11.5	0.70	44.4
0.25	14.5	0.75	48.6
0.30	17.5	0.80	53.1
0.35	20.5	0.85	58.2
0.40	23.6	0.90	64.2
0.45	26.7	0.95	71.8
0.50	30.0	1.00	90.0

Section 9.4. Taking an Evasive Action

1. Taking an Evasive Action at a Given Distance

For $V_M > V_K$ determine the sector within which a maneuvering ship can operate without being approached by an enemy K at a distance closer than $Д_3$ regardless of the course the enemy steers. If t_3 is the interval between the time the enemy was detected and the beginning of the maneuver (the delay time) and f is the maximum error in determining the relative position of the maneuvering ship and enemy then, in order to solve the problem, it is necessary to perform the following:

- calculate the auxiliary quantity

$$K = Д_3 + V_K t_3 + f; \qquad (9.26)$$

- find the maximum relative bearing of the maneuvering ship

$$Q_{\Pi p} = Q + \Delta Q, \qquad (9.27)$$

where Q is the critical bearing (obtained from Table 9.1 by using the ratio V_M/V_K) and ΔQ is the critical bearing correction (obtained from /264

Table 9.1 by using the ratio $R/Д_0$); and

- calculate the bearings of the boundaries of the dangerous course sector (Fig. 9.14):

$$K_{M(0П)} = П_{MK0} \pm Q_{Пр}, \tag{9.28}$$

where $П_{MK0}$ is the bearing of the site where the enemy ship was last detected taken from the point where the maneuvering ship begins an evasive action.

Any course of the maneuvering ship outside the danger sector satisfies the conditions of the problem.

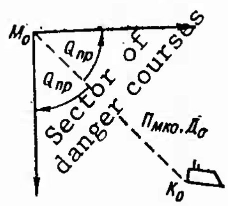


Fig. 9.14. Taking an evasive action at a given distance

2. Passing the Reference Ship at a Given Distance

If ships K and M are steering steady courses at constant speeds and if the distance between them decreases then, at a certain time, after becoming minimal, the distance will begin to increase. Given K_K, V_K, $П_0$ (q_{K0}), $Д_0$ and V_M. Find the course that the maneuvering ship should steer to pass the reference ship at a given distance $Д_3$.

On a maneuvering board (Fig. 9.15): from the initial relative position M'_0 of the maneuvering ship draw tangents to the maneuvering board circle corresponding to the distance $Д_3$. Mark one of the points of tangency as the relative position M'_1 of the maneuvering ship at the time of completion of the maneuver. Find the relative movement vector $\bar{S}_{\rho M}$ (its origin is point M'_0 and its end point is M'_1). If a maneuver for passing several ships is being calculated, then point M'_1 is selected so that passing of one of the ships would not result in an undesirable closing the distance to the others. If passing of one ship /266

is being calculated, then point M_1' is selected so that vector $\bar{S}_{\rho M}$ would not cross the course line of that ship. The construction of the velocity triangle and the calculation of the maneuvering time are the same as those used in solving the problem of changing station in the shortest time interval (see Section 9.2, Subsection 1).

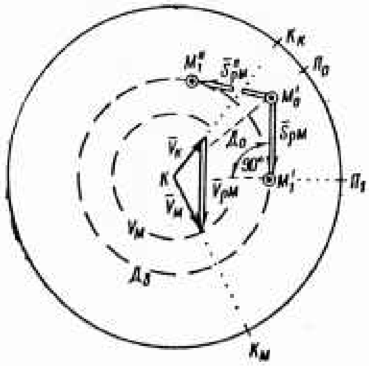


Fig. 9.15. Passing the reference ship at a tiven distance (on a maneuvering board)

On a chart (Fig. 9.16) the problem is solved in a similar manner. The position and velocity triangles are constructed at point K_0. In addition, the movement triangle $M_0M_1'M_1$ is constructed (see Section 9.1, Subsection 3). The maneuvering time is $t = S_M/V_M = S_K/V_K$.

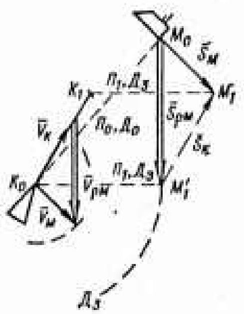


Fig. 9.16. Passing the reference ship at a given distance (on a chart and when $V_M < V_K$)

3. Passing the Reference Ship at a Maximum Distance

For $V_M < V_K$ find the course which the maneuvering ship should steer to pass the reference ship at a maximal distance. The course and speed of the reference ship are known.

On a maneuvering board (Fig. 9.17) the solution of the problem should begin with the construction of the accessible position sector (see Section 9.2, Subsection 4). At the base of the perpendicular drawn from the center of the maneuvering board to the accessible position sector boundary farthest from the ship mark the relative position M_1' of the maneuvering ship at the end of the maneuver. Vector $\bar{V}_M$ is perpendicular to the boundary of the accessible position sector. (Check: the center of the diagram, the end of vector $\bar{V}_M$, and the point M_1' must lie on the same straight line.) The maneuver time is $t = S_\rho/V_\rho$.

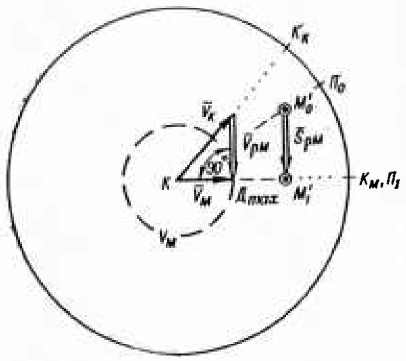


Fig. 9.17. Passing the reference ship at a maximum distance (on a maneuvering board)

On a chart (Fig. 9.18) the problem is solved in a similar manner. The position and velocity triangles are constructed at point K_0. In /268
addition, movement triangle $M_0M_1'M_1$ is constructed (see Section 9.1, Subsection 3). The maneuvering time is $t = S_M/V_M = S_K/V_K$.

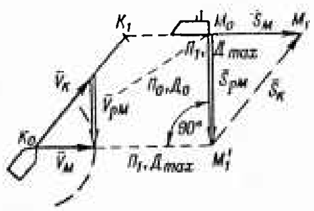


Fig. 9.18. Passing the reference ship at a maximum distance (on a chart)

4. Changing the Bearing of the Reference Ship in the Shortest Time Interval

Given: K_K, V_K, Π_0 (q_{K0}), $Д_0$, Π_3 and V_M. Find the course which the maneuvering ship should steer to acquire a bearing Π_3 relative to the reference ship in the shortest time interval and determine the maneuvering time.

The course of the maneuvering ship is:

$$K_M = \Pi_3 \pm 90°. \tag{9.29}$$

In the formula the sign is "+" if the bearing changes clockwise during the maneuver and it is "-" if the bearing changes counterclockwise. In order to find the maneuvering time it is necessary, after constructing the velocity triangle (Fig. 9.19), to find vector $\bar{V}_{\rho M}$ (its origin is the end of vector $\bar{V}_K$ and its end point is the end of vector $\bar{V}_M$). Construct the position triangle. From the center of the maneuvering board (point K_0, when solving the problem on a chart) draw the line of the given bearing Π_3 and, from the initial relative position M_0' (point M_0 when solving the problem on a chart), draw the line /269 of relative movement of the maneuvering ship (parallel to vector $\bar{V}_{\rho M}$ and in the same direction). At their point of intersection mark the relative position M_1' of the maneuvering ship at the end of the maneuver. The maneuvering time is $t = S_\rho/V_\rho$. In addition, when solving the problem on a chart, construct the movement triangle (see Section 9.1, Subsection 3). The maneuvering time then is $t = S_M/V_M = S_K/V_K$.

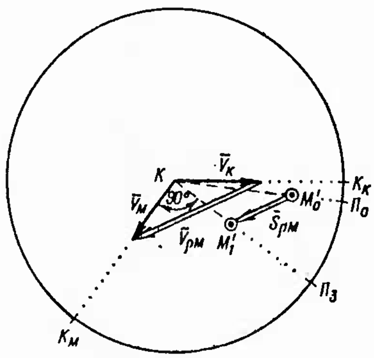


Fig. 9.19. Changing bearing in the shortest time interval

Section 9.5. Tracking the Reference Ship

Given: K_K, V_K, Π_0 (q_{K0}), $Д_0$ and V_M. For $V_M < V_K$ calculate the courses which the maneuvering vessel should keep to maintain the distance to the target $Д_2$ and $Д_1$ over a period of time as long as possible; determine the time spent on each of these courses.

<u>On a maneuvering board</u> (Fig. 9.20): plot the auxiliary point $Ф'$ in the direction opposite to the course of the reference ship, at a distance $x = (V_K/V_M)\, Д_3$ from the center of the maneuvering board. Along the tangents to the board circle, corresponding to the distance $Д_2$, draw a broken line for the relative movement from point M'_0 to point $Ф'$ in such a way that all the intermediate relative positions M'_1....are inside the board circle corresponding to distance $Д_1$. At the point of intersection of the last relative movement line with circle $Д_1$, mark the relative position M'_3 of the maneuvering ship at the end of the maneuver. Find the relative movement vector $\bar{S}_{\rho M}$ (its origin is point M'_0 and its end point is M'_1). After solving the velocity triangle, in the same way as it was done in the section dealing with the changing station in the shortest time interval (Section 9.2, Subsection 1) and after selecting, from the two possible solutions, the one corresponding to the greater maneuvering time (i.e., to the lesser relative velocity $V_{\rho 1}$), find the velocity vector $\bar{V}_{M1}$ of the maneuvering ship at the first stage of the maneuver and obtain its direction (the course K_{M1} of the maneuvering ship). Calculate the time spent on this /270
course from $t_1 = S_{\rho 1}/V_{\rho 1}$. In a similar manner determine the courses for other stages of the maneuver and find the time spent on each course. (Check: the relative position M'_3 of the maneuvering ship at the time of completion of the maneuver, the center of the maneuvering board, and the end of the velocity vector $\bar{V}_{M3}$ of the maneuvering ship during the last stage of the maneuver must lie on the same straight line).

<u>On a chart</u> the problem is solved in a similar manner. In addition to the above, the movement triangle is constructed for each stage of the maneuver and the position of the maneuvering ship and of the reference ship are plotted for each stage.

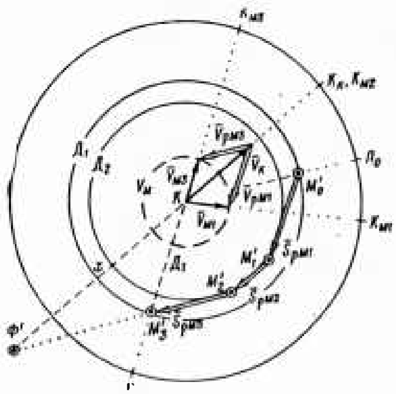


Fig. 9.20. Tracking the reference ship

Section 9.6. Determining Motion Characteristics of a Target

1. Determining Motion Characteristics of a Target From Bearings and Ranges

On a maneuvering board (Fig. 9.21) ship M is located at the center. /271
By using the measured bearings and distances $П_{MKi}$ and $Д_i$ from the ship, the relative positions K'_1, K'_2, ...K'_i....K'_n of the target are plotted. To find the velocity vector $\bar{V}_K$ of the target, the equation (9.6) is used: $\bar{V}_K = V_M + V_{\rho K}$. Measure the length $S_{\rho(1n)}$ of the target relative movement vector $\bar{S}_{\rho K}$ and calculate the relative velocity $V_\rho = S_{\rho(1n)}/t$. From the end of vector $\bar{V}_M$ parallel to vector $\bar{S}_{\rho K}$ and in the same direction, plot vector $\bar{V}_{\rho K}$ whose length, in the chosen velocity scale, is equal to V_ρ. The point obtained is the end of vector $\bar{V}_K$ (its origin is the center of the board). Its direction (course K_K of the target) and length (speed V_K of the target) are obtained from the diagram.

In order to make a naval engagement plot on a chart or on a maneuvering board (Fig. 9.22), the dead reckoning position of the ship is plotted at the time of each measurement and the bearing and distance measured to the target are also plotted. The first and last positions of the target are connected by a straight line whose direction indicates the course of the target. The speed of the target is /272
$V_K = S_{K(1n)}/t_{1n}$, where $S_{K(1n)}$ is the distance between the first and

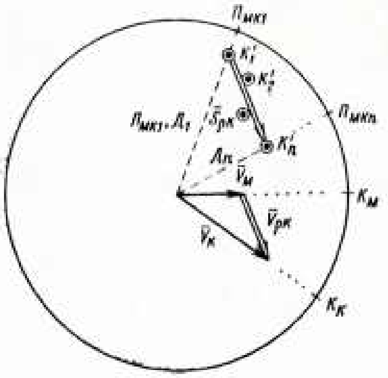


Fig. 9.21. Determining motion characteristics of a target from bearings and distances (on a maneuvering board)

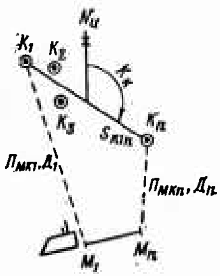


Fig. 9.22. Determining motion characteristics of a target from bearings and distances (on a chart)

last positions of the target and t_{1n} is the interval of time between measurements.

2. Determining Motion Characteristics of a Target From a Distance and Three Bearings

At time T_1 one measures the target bearing $П_{МК1}$ and distance $Д_1$ and at time T_2 and T_3 only the bearings $П_{МК2}$ and $П_{МК3}$. It is desirable that the intervals of time between measurements be the same ($T_3 - T_2 = T_2 - T_1 = t$). For a constant overall period of surveillance this increases the accuracy in determining motion characteristics of a target and simplifies calculations. Described below is a solution of

the problem for the case where this requirement is satisfied.

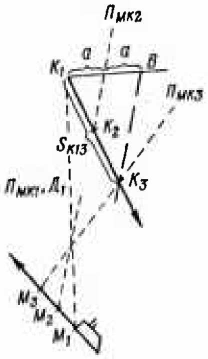


Fig. 9.23. Determining motion characteristics of a target from a distance and three bearings (on a chart)

In order to prepare a naval engagement plot (Fig. 9.23) on a chart or on a maneuvering board, plot the dead reckoning positions M_1, M_2, and M_3 of your own ship at the time of measurement. On the bearing line Π_{MK1}, at a distance $Д_1$ from point M_1, plot the position K_1 of the target at time T_1. From points M_2 and M_3 draw the bearing lines Π_{MK2} and Π_{MK3} /273 obtained at time T_2 and T_3, respectively. Through point K_1 draw an arbitrary auxiliary line almost perpendicular to the line of the first bearing; measure the length of the segment a obtained through the intersection of the auxiliary line with the line of the second bearing. From the point of intersection plot a segment equal to segment a. From the auxiliary point B obtained, draw a straight line parallel to the line of the second bearing and mark the point of its intersection with the line of the third bearing as the position K_3 of the target at time T_3. Connect points K_1 and K_3 with a straight line and measure its bearing (target's course) and distance $S_{K(13)}$ (the length of segment K_1K_3) traveled by the target. Calculate the speed of the target from the formula

$$V_K = S_{K(13)}/T_{13}.$$

3. Determining Motion Characteristics of a Target From Four Bearings (the Imaginary Bearing Method)

Having detected the target (time T_0 and target bearing Π_{MK0}) the maneuvering ship steers a course equal to the target bearing (Fig. 9.24).

The target bearings Π_{MK1}, Π_{MK2}, and Π_{MK3} (times T_1, T_2 and T_3) are measured on this course while steaming at the lowest possible speed. At time T_3, during measurements of the third bearing, the ship increases her speed and begins turning. A fourth bearing Π_{MK4} (time T_4) is measured on the new course. It is desirable that the time intervals between measurements be the same ($T_4 - T_3 = T_3 - T_2 = T_2 - T_1 = t$). Described below is a solution of the problem for the case where this requirement is satisfied.

Approximate evaluation of the target range:* calculate an imaginary

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* A. N. Motrokhov. Determining Distance to the Reference Ship. Morskoy sbornik, 1972, No. 9.

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increment in bearing during the interval of time between the detection of the target and the measurement of bearing Π_{MK1} from the following formula:

$$\Delta\Pi_{\Phi} = \frac{t_{01}}{t_{12}} \Delta\Pi_{12}, \qquad 9.30)$$

where $\Delta\Pi_{12} - \Pi_{MK2} - \Pi_{MK1}$; $t_{01} = t_1 - t_0$; $t_{12} = T_2 - T_1$.

Calculate the difference between the actual and imaginary increments in bearing: /274

$$\Delta_{\Phi} = \Delta\Pi_{01} - \Delta\Pi_{\Phi}, \qquad (9.31)$$

where $\Delta\Pi_{01} = \Pi_{MK1} - \Pi_{MK0}$.

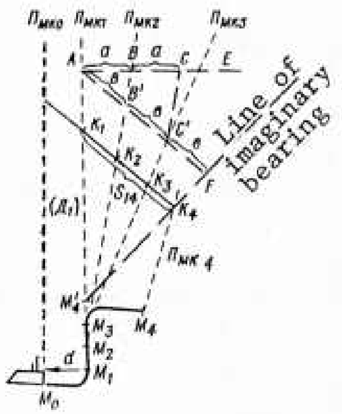

Fig. 9.24. Determining motion characteristics of a target from four bearings (the imaginary bearing method)

The distance to the target at the time of its detection is:

$$Д_0 = 57.3° \frac{d}{\Delta_\Phi} . \qquad (9.32)$$

where d is the distance between point M_1 and the line of bearing $П_{MK0}$ at the time of detection of the target, in cable lengths.

In order to make a plot (Fig. 9.24) on a chart or on a maneuvering board, plot the dead reckoning positions M_0, M_1, M_2, M_3, and M_4 of your own ship, obtained at the time of each measurement and from these points draw the lines of the measured bearings. Mark off segment $Д_1$ equal to the assumed distance to the target on the line of the first bearing and plot auxiliary point A. Through this point draw an arbitrary line AE. Measure the length of segment a formed by the line of the second bearing and mark off a segment equal to segment a from the point of intersection B. Through point C obtained draw a line parallel to the line of the /275 second bearing until it intersects the line of the third bearing. Connect point A with the auxiliary point C' obtained and measure the bearing of the connecting line (this is the approximate course of the target). Measure the lengths of the segments formed by the lines of the second and third bearings on this line (by construction they must be equal). After plotting from point C' a segment equal in length to the above segments, mark the auxiliary point F (the target would be located here at time T_4 if the assumption about the distance to it at the initial time T_1 were correct).

Plot point M_4' where your own ship would be located at the time of measurement of the fourth bearing if, at time T_3, she did not change her speed and did not begin turning. Connect point M_4 with point F by means of a straight line, i.e., the imaginary bearing line (it almost coincides with the locus of the points F corresponding to various assumptions made about the initial distance to the target). At the point of intersection of the imaginary bearing $M_4'F$ with the line of bearing $П_{MK4}$ actually measured at time T_4, mark the position K_4 of the target. Through this point draw the course line AF and at its intersection with the lines of the first, second and third bearings mark the positions K_1, K_2, and K_3 of the target. Measure the distance $S_{K(14)}$ from point K_1 to K_4 and calculate the speed of the target $V = S_{K(14)}/t_{14}$.

4. Determining Motion Characteristics of a Target With the Target Bearing Remaining Constant

If the bearing on a target does not change, then OBP = 0 and the absolute value of BP_K is equal to BP_M. From your own relative bearing and speed select the value of BP_M from the BP Table.

If the speed of the target is known, then, by using V_K and $BP_K = BP_M$, find the target relative bearing q_K from the Table (in column V_K find the value of BP equal to the previously selected value BP_M and note to what relative bearing it corresponds). If the target is moving toward us, i.e., $VIR_K = OVIR - VIR_M$ is negative, then the relative bearing of the target is an acute angle; if the target is moving away from us (VIR_K is positive), then it is an obtuse angle. /277

If the relative bearing of the target is known, then from the BP Table, by using q_K and $BP_K = BP_M$, obtain the speed of the target. Special tables may be used for these calculations.

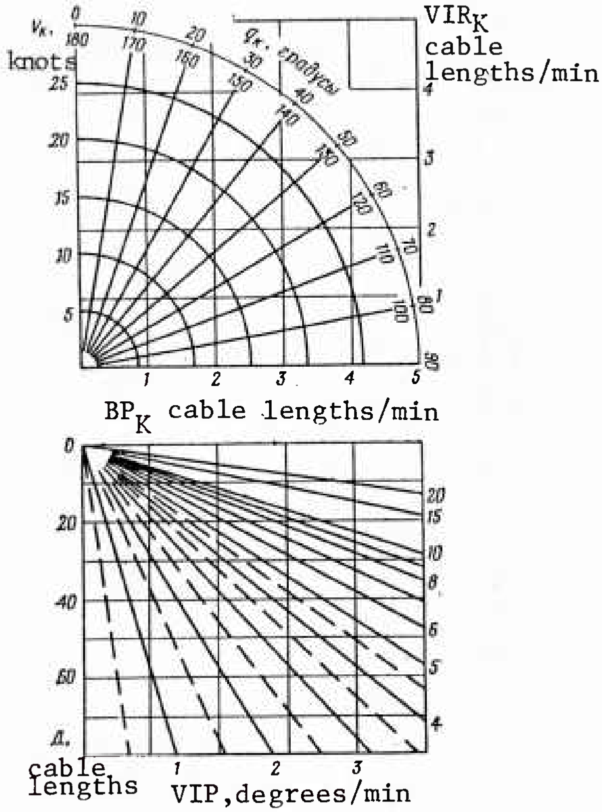

Fig. 9.25. Nomogram for determining motion characteristics of a target when maneuvering and tracking the target

5. Determining Motion Characteristics of a Target When Maneuvering and Tracking the Target

The maneuvering ship constantly tracks the target so that the course of the maneuvering ship is equal to the target bearing. Moreover, if V_M is expressed in the same units as OVIR, then:

$$BP_K = OBP; \tag{9.33}$$

$$VIR_K = OVIR = V_M \tag{9.34}$$

It is convenient to measure the bearing and range every minute; then $VIP = \Delta\Pi/\Delta t$ and $OVIR = \Delta Д/\Delta t$ will numerically be equal to the change in bearing and distance per minute. Calculate VIR_K from Formula (9.34). By using the nomogram (Fig. 9.25) and the values of VIP, Д, and VIR_K, find the relative bearing and speed of the target.

CHAPTER 10

MARINE HYDROMETEOROLOGY* /278

Section 10.1. Meteorology

The meteorological elements are quantities which characterize the physical condition of the atmosphere. The temperature of the air is expressed in degrees Celsius (in the USA and England--in degrees Fahrenheit); on ships it is measured by means of the dry-bulb thermometer of the psychrometer.

Air humidity: absolute humidity is the amount of water vapor, in grams, contained in one cubic meter of air; relative humidity is the ratio between the amount of water vapor contained in the air and the amount saturating the air at a given temperature. The dew point is the temperature at which the water vapor in the air, cooled at constant pressure, achieves saturation. On ships the humidity of the air is determined by means of an aspiration psychrometer (after correcting the readings of the wet-bulb and dry-bulb thermometers, the psychrometer tables are used).

Atmospheric pressure is the force which the air exerts per unit area (it is equal to the weight of the vertical column of air located over that area). It is expressed in millibars or in millimeters of the mercury column (1 mm of the mercury column = 1.33 mb; 1 mb = 0.75 mm of the mercury column; 1 bar = 10^5 Pa). On ships it is measured by means of the aneroid barometer; variations in pressure with respect to time are recorded by a barograph. An isobar is the geometric locus of points on the earth's surface where, at the given time, the pressure, referred to sea level, is the same.

Wind is the horizontal component of motion of air relative to the earth's surface. The direction of the wind is that direction from which the wind blows. Wind velocity is expressed in m/sec and sometimes in knots. On weather maps the direction of the wind is indicated by an arrow and its velocity by feathers. One small feather designates 2.5 m/sec; a large feather--5 m/sec; and a triangle--25 m/sec. Wind /279
force is the conventional number characterizing the effect of the wind on the physical condition of the surface of the sea. On ships the direction and speed of the wind are measured by means of instruments of the ship's meteorological system; if the system is not available, the direction of the relative (apparent) wind is determined by eye from the pennant and compass and the speed is measured by an anemometer.

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* L. S. Shifrin participated in writing of Chapter 10.

The velocity vector of the true wind is:

$$\bar{U} = \bar{W} - \bar{V}_{(K)} \qquad (10.1)$$

where $\bar{W}$ is the velocity vector of the relative wind and

$\bar{V}_{(K)}$ is the velocity vector of the course wind caused by ship's motion.

The vector $\bar{V}_{(K)}$ is opposite to the velocity vector of the ship (the bearing of the course wind is equal to the course of the ship). Calculations with the aid of Formula (10.1) are performed on a true wind velocity calculator or on a maneuvering board (Fig. 10.1). In this case one should take into account that 1 knot = 0.5 m/sec (approximately).

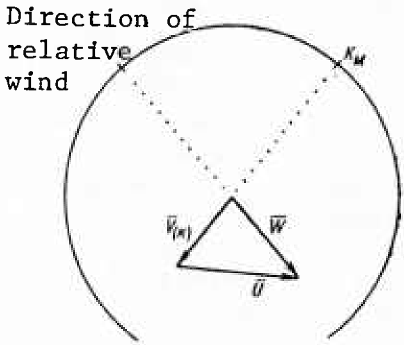


Fig. 10.1. Calculation of the true wind

In the northern hemisphere the direction of the wind velocity vector deviates to the right of the direction of the horizontal pressure gradient (of the vector perpendicular to the isobars and oriented in the direction of reduced pressure) and in the southern hemisphere, to the left--at an angle of approximately 75° over the sea and 50° over dry land. With an increase in altitude up to 500-600 meters above the /280
earth's surface this angle approaches 90°. The velocity of the surface wind U, in meters/sec, in terms of the value G_r of the horizontal pressure gradient in mb per 100 km is:

$$U = kG_r \qquad (10.2)$$

where the mean value of the coefficient k is 6.5 at a latitude of 30°; 4.5 at a latitude of 50°; 3.4 at a latitude of 70°; and 3.2 in the polar region latitudes.

The meteorological visibility range is the minimal distance at which

a long, dark object ceases to be distinguishable against the sky near the horizon during the daylight hours. It is expressed in meters, kilometers, or miles.

Radar observability is the ratio of the mean value of the actual radar detection range of a surface target to the radar record book value. If the ratio is less than 0.9--reduced observability (1 point); from 0.9 to 1.1--normal observability (2 points); from 1.1 to 2.0--increased observability (3 points); greater than 2.0--long-range observability (4 points).

Atmospheric phenomena: (the symbol given in the parentheses below is used on weather maps). Fog (≡) is the accumulation, in the atmosphere near the ground, of the finest drops of water or ice crystals, in the presence of which the horizontal visibility range is less than 1 km; mist (=) is the accumulation of drops in the presence of which the visibility ranges from one to 10 km. Fogs are formed as follows: advection fog--by the movement of warm moist air over a cooler surface; steam fog (steaming of the sea)--in winter, over basins free of ice, during condensation, in the cold air, of moisture evaporating from the surface of a warmer sea; radiation fog--over dry land or compact ice, when the skies are clear, as a result of the radiation cooling of the earth's surface.

Clouds (Table 10.1) are accumulations of the finest drops of water or ice crystals suspended in the atmosphere. Cloud cover is the degree to which the firmament is covered with clouds. It is expressed in points from 0 to 10 (1 point designates 1/10 of the firmament).

Atmospheric precipitations consist of drops of water or ice formations falling from the clouds and reaching the earth's surface. Forms of precipitation are: rain (•), drizzle (,), snow (*), soft hail (△) and hail (▲). Types of precipitation: drizzling rains--they fall in /281
the form of fine drops of water or snowflakes from stratus or stratocumulus clouds and are of a very low intensity; steady rains--they fall in the form of drops of water or snowflakes of average size from altostratus or nimbostratus clouds; they cover large areas and are of an average intensity; torrential rains--they fall in the form of large drops of water, flakes of snow, soft hail or hail from cumulonimbus clouds; they are not long in duration and reoccur after short intervals of time; they cover smaller areas than steady rains and the coverage is irregular; they can be extremely intense.

The amount of precipitation is the thickness of the layer of water which would be formed on the earth's surface if the water did not soak into the ground or flow into rivers; for snow, soft hail, or hail precipitation it is the thickness of the layer of water which would be formed if the snow melted.

Table 10.1 /282

Classification of Clouds

Types of clouds (International designation)	Symbols on weather maps	Description
High clouds (altitude of the lower cloud base is greater than 6000 m)		
Cirrus (Ci)	fibrous dense hook-shaped	
Cirrocumulus (Cc)		
Cirrostratus (Cs)	covering the entire sky nonpropagating across the sky	They are in form of filaments, hooks, or fine white veils; during the day they do not weaken the shadows from objects on the earth's surface.
Medium clouds (from 2000 to 6000 m)		
Altocumulus (Ac)	translucent striated in combination with As	They are in the form of a layer of large fleecy clouds or laminated sheet. The sun shines through them as through a frosted glass.
Altostratus (As)		
Low clouds (lower than 2000 m) /283		
Stratocumulus (Sc)		Low heavy clouds, gray or dark-gray in color
Stratus (St)		
Nimbostratus (Ns)		
Vertical formation clouds		
Cumulus (Cu)	flat heavy	Dense vertical clouds with flat bottoms and curling tops
Cumulonimbus (Cb)		

On weather maps the symbols used for other atmospheric phenomena which could be dangerous to ships are:

▽ - squall;)(- tornado;  - light or moderate thunderstorm;  - violent thunderstorm.

An air mass is a layer of air in the trosposphere 1 to 10 km in height and up to several thousand kilometers in length. Physically the air is relatively homogeneous and differs sharply from that of adjacent regions. Air masses are formed in anticyclones and in slowly moving cyclones where the air remains for a long period of time (several days or more) over a vast region of the ocean or continent with a uniform cover. Air masses are classified according to their region of formation, i.e., arctic or antarctic (A); polar or temperate (P or U); tropical (T); and equatorial (E). Those formed over a continent or the ice masses of the Arctic basin are classified as continental air masses (cA, cU, cT) and those formed over oceans are classified as maritime air masses (mA, mU, mT).

A cold air mass migrating from a cold region to a warmer region lowers the temperature and gradually becomes warmer. A warm air mass migrating from a warm region to a colder region raises the temperature and gradually becomes cooler. A local air mass is one that remains in the same region for a prolonged period without undergoing any substantial change in its properties.

As a rule, a warm air mass is stable and a cold air mass is unstable; a cold air mass with a high relative humidity is even more unstable. Instability increases over dry land whose surface is warmed by the sun during the day, and above the sea when the radiation cooling of the upper layers of the moist air takes place during the night. With significant instability, intensive ascending air currents are generated. In a mass of moist air they result in the formation of heavy cumulus /284
and cumulonimbus clouds, showers, thunderstorms, and squalls.

An atmospheric front is the line of intersection of a frontal surface, which is assumed to be the transition zone between two adjacent air masses, with the earth's surface.

The basic conventional symbols are: /285

 warm front (migrating in the direction of a colder air mass);

 cold front (migrating in the direction of a warmer air mass);

 slow-moving front (stationary);

 occlusions (formed as a result of the merging of a warm front with a cold front that has overtaken it.

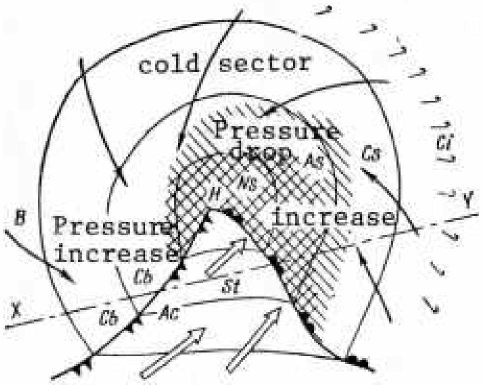
Table 10.2

Precipitation Symbols on Weather Maps

Type of precipitation			Intensity
Drizzle	Rain	Snow	
,	•	*	Light with interruptions
, ,	• •	* *	Light and continuous
, ,	• •	* *	Moderate with interruptions
, , ,	• • •	* * *	Moderate and continuous
, , ,	• • •	* * *	Heavy with interruptions
, , , ,	• • • •	* * * *	Heavy and continuous
	• ▽	* ▽	Light showers
	• ▽	* ▽	Moderate or heavy showers

<u>Extratropical cyclones</u> (cyclones in the temperate latitudes) are regions of reduced pressure encompassed by a system of closed isobars. They have a diameter of approximately 500 miles and a pressure at the center of 980-990 mb; in the northern hemisphere they generally move toward the east and northeast, and in the southern hemisphere--toward the east and southeast. Their centers on charts are indicated by the letter "H". The wind in a cyclone is directed from the periphery toward the center and has a counterclockwise circulation in the northern hemisphere; in the southern hemisphere--a clockwise circulation. Cyclones occur in series (up to five in a series) in the principal atmospheric fronts classified A and U, U and T. Intermediate anticyclones are formed between the cyclones in a series.

A young cyclone (Fig. 10.2) has a warm sector filled with warm



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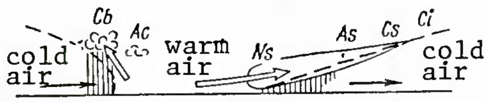

b

Fig. 10.2. Young extratropical cyclone:

a - in the plan view; b - cross-section along line XY

air and a cold sector filled with cold air that are separated by warm and cold fronts. It moves approximately parallel to the direction of the isobars of the warm sector (parallel to the straight line connecting the centers of the regions of maximum increase and maximum drop in pressure). See Table 10.3 for weather when fronts are approaching or passing through. In the northern hemisphere when a cyclone is moving over the sea the regions of highest waves are located more to the west and southwest of the cyclone center and in the southern hemisphere--more to the west and northwest. Cyclone occlusion (Fig. 10.3) begins when a cold front, which moves more rapidly, overtakes a warm front and joins it. It is accompanied by the cessation of the pressure drop and then by an increase in pressure at the center of the cyclone and by a decrease in wind velocity and velocity of the cyclone center.

Determining the position of a ship with respect to the center of a cyclone: if one stands with his back to the wind then, in the northern hemisphere, the center of the cyclone will be ahead, approximately 70° to the left (in the southern hemisphere--to the right) of the direction of the wind (the baric wind law). /288

Anticyclones are regions of increased pressure encompassed by a system of closed isobars. On charts their centers are designated by the letter "B". The pressure at the center is 1015 to 1030 mb. The

Table 10.3

Basic weather characteristics during the passage of atmospheric fronts

Front (velocity in knots)	Pressure	Wind	Temperature	Clouds	Precipitation and visibility
Warm front (20-30)	At first the pressure drops slowly, then rapidly; behind front the pressure drop slows down, ceases, or increases slowly	As the front approaches the wind freshens. With the passage of the front, wind direction changes sharply to the right in N hemisphere and to the left in S hemisphere	Behind the front temperature rises	Cirrus hook-shaped, cirrostratus, altostratus, nimbostratus; behind the front are stratus clouds or temporary clearing	Steady rains; behind the front they cease or turn to drizzle, fog, or mist
Cold front of the first kind (20-30)	Directly ahead of the front the pressure falls rapidly; behind the front it rapidly increases	Ahead of the front the wind gradually freshens; with the passage of the front it intensifies sharply; its direction changes sharply to the right in the N hemisphere and to the left in the S hemisphere	Behind the front temperature drops	Directly ahead of front--cumulus clouds; with the passage of front--cumulonimbus; behind the front--nimbostratus, altostratus, clearing (sometimes cumulus and cumulonimbus clouds appear after several hours)	Showers; behind the front there are steady rains, gradually stopping. Improvement in visibility

Table 10.3 (continued)

Basic weather characteristics during the passage of atmospheric fronts

Front (velocity in knots)	Pressure	Wind	Temperature	Clouds	Precipitation and visibility
Cold front of the second kind (25-40)	Directly ahead of the front the pressure drops rapidly; behind the front it rapid-increases	Ahead of the front the wind gradually intensifies; with the passage of the front it intensifies sharply; its direction changes sharply to the right in the N hemisphere and to the left in the S hemisphere	Temperature drop is sharper	Ahead of the front--altocumulus lens-shaped clouds; with passages of front--cumulonimbus; there is clearing behind the front (cumulus and cumulonimbus clouds may appear after several hours)	Showers, thunderstorms; when the front passes they quickly cease; improvement in visibility
Occulusions	At first, just as before the approach of a warm front, and then--just as in the passage of a cold front and following it, but with less sharp changes in the weather				

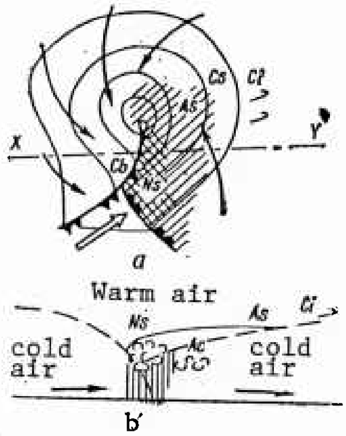

Fig. 10.3. Cyclone occlusion:

a - in the plan view; b - cross-section along line XY

wind is directed from the center of the anticylcone toward the periphery and in the northern hemisphere has a clockwise circulation while in the southern hemisphere--a counterclockwise circulation. Slightly cloudy dry weather and light wind prevail in the central parts of anticyclones. With significant moisture in the air during the cold half of the year, stratus and stratocumulus clouds can be observed here. /289

Tropical cyclones are small (usually their diameter does not exceed 200-300 miles) and have no atmospheric fronts. They are generated over the oceans in latitudes ranging from 5 to 20° in both hemispheres. The pressure at the center of the cyclone is 950-960 mb. At first they move toward the west with a velocity of 5-15 knots. Then, in the northern hemisphere, the direction changes toward the north and northeast; in the southern hemisphere--toward the south and southeast. The velocity increases up to 20-30 knots. Certain cyclones have a loop-shaped path which makes it difficult to avoid them. A hurricane wind (up to 60 and sometimes 100 m/sec) and violent seas, which at the center of a cyclone are irregular in nature, pose great danger to ships of all types.

Indications of an approaching tropical cyclone are: changes in the daily pressure variation; drop in pressure; an intensified swell /290 coming from the direction which does not coincide with the direction of the wind; stifling weather; a calm followed by a rapid freshening of the wind; the appearance of cirrus and then cirrostratus, altocumulus, and heavy cumulonimbus clouds with rain showers; and intense

radio-reception interference.

The selection of a course in order to avoid a tropical cyclone is made in advance in conformity with storm announcements and weather reports. If the first signs of an approaching tropical storm are detected aboard ship the position of the ship with respect to the cyclone center and path must be determined. In order to determine the direction toward the center of the cyclone one should be guided by the baric wind law and by the direction of the swell of the sea (the swell spreads out from the center of the cyclone in concentric circles). If the direction of the wind changes clockwise, the ship is to the right of the cyclone path and if it changes counterclockwise, she is to the left of the cyclone path. If the direction of the wind does not change, the ship is on the cyclone path. If the pressure drops the ship is in the forward half of the cyclone and if it increases the ship is in the rear half. The dangerous half of the cyclone is the right half with respect to its path in the northern hemisphere and the left half in the southern hemisphere. /291

The rule for avoiding a tropical cyclone (Fig. 10.4) is: bring the wind on the starboard in the northern hemisphere and on the port in the southern hemisphere, making the relative bearing so as to move away from the center of the cyclone as quickly as possible.

Using weather forecasts and announcements. Weather maps compiled at hydrometeorological centers and observatories serve as a basis for

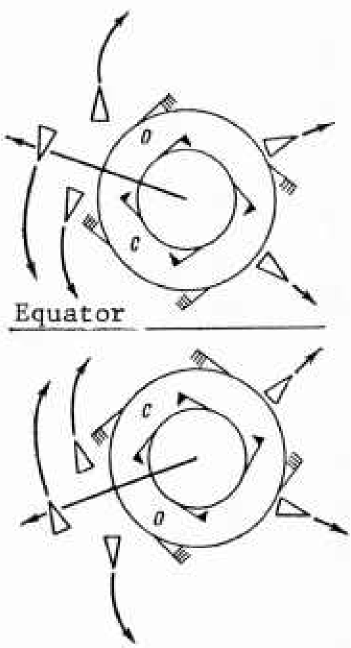

Fig. 10.4. Avoiding a tropical cyclone

weather forecasting. The weather at each station from which the information is received is indicated on the charts (Fig. 10.5) together with isobars, atmospheric fronts and the precipitation zones. Weather forecasts transmitted by radio must be received regularly by each ship at sea. Since changes, which are difficult to foresee at the time of compilation of a weather forecast, may arise in the atmosphere, the forecast must be updated aboard ship on the basis of the weather actually observed. To do so one should take into account the general weather conditions and use both radio weather forecasts and the facsimile transmissions of weather maps, if possible.

From the radio forecasts, plot the centers of cyclones and anticyclones on a map; designate with arrows their directions and velocities; indicate the position of atmospheric fronts and draw the characteristic isobars. Mark where the centers of cyclones and anticyclones may be located at the present time; in conformity with the acutally observed weather, determine more precisely the position of the ship with respect to the approaching cyclone (atmospheric front, anticyclone) and estimate what deviations in the weather from the forecasts should be ex- /293
pected. In addition, it is necessary to take into account local weather signs.

1. Signs of imminent worsening of the weather (freshening of the wind, reduced visibility, steady rains) with the approach of a warm front are: pressure drop; the appearance of hook-shaped cirrus clouds rapidly moving toward the zenith and alternating with cirrostratus and stratus clouds in the western part of the horizon; difference in the directions of movement of clouds at various levels; difference between the direction of movement of clouds and the direction of the surface wind (in the northern hemisphere cirrus and cirrostratus clouds move to the right with respect to the direction of the wind); intensification of the seas; difference between the direction of the sea swell and the direction of the wind; abnormally improved visibility and the appearance of mirages; abnormally increased audibility of sounds in the air; the appearance of a halo or corona around the moon or sun and the intense twinkling of the stars at night; a bright red morning glow; the setting of the sun in the evening in dense clouds; a rise in air temperature in the evening; smoke from the stack drifts downward.

2. Signs of worsening weather (freshening of the wind, steady rains) with the approach of a cold front are: sharp drop in atmospheric pressure; the appearance of cirrocumulus and altocumulus lens-shaped clouds; instability of the wind; heavy radio-reception interference; detection by radar of heavy cloud accumulations; rapid development of cumulonimbus clouds; chaotic appearance of the sky; characteristic noise of an approaching storm or squall.

3. Signs of improvement in weather following the passage of a cold front are: rapid rise in atmospheric pressure; sharp turning of the

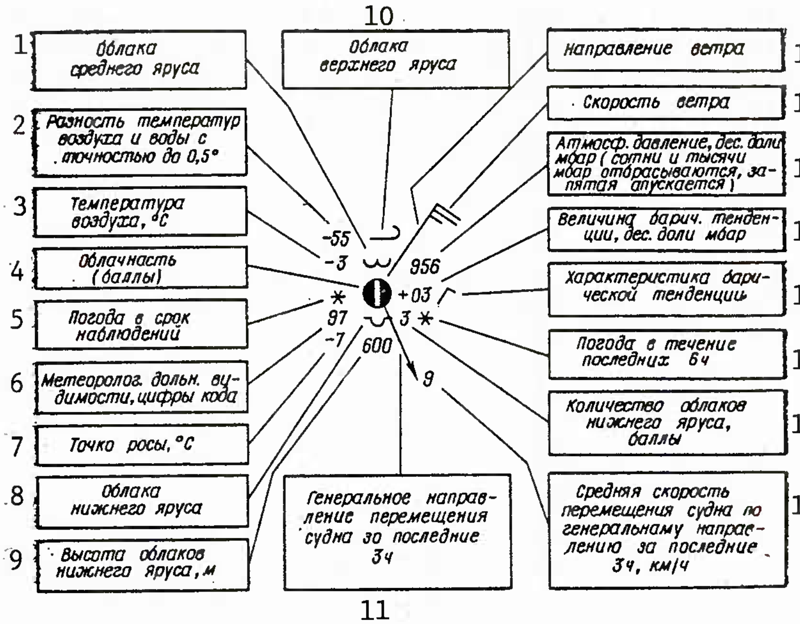

Fig. 10.5. Diagram showing meteorological data plotted around the circle representing the station on a weather map

Key to Fig. 10.5:

1. Medium clouds
2. Difference between air and water temperature with an accuracy of up to 0.5°
3. Air temperature, °C
4. Cloud cover (points)
5. Weather during observations
6. Visibility range, code numbers
7. Dew point, °C
8. Low clouds
9. Height of low clouds
10. High clouds
11. General sailing direction of the ship during the last 3 hours
12. Wind direction
13. Wind velocity
14. Atmospheric pressure, tenths of a millibar (the hundredths and thousandths of a millibar are disregarded; the decimal point is omitted)
15. Atmospheric pressure trend, tenths of a millibar
16. Characteristic of the pressure trend
17. Weather during the last 6 hours
18. Amount of low clouds (points)
19. Average speed of ship along the general direction during the last 3 hours, km/hr

wind to the right in the northern hemisphere (to the left--in the southern hemisphere); improvement in visibility; daily atmospheric pressure becomes regular; increase in the diameter of the corona around the moon; lowering of the temperature.

Section 10.2. Oceanography

The chemical and physical properties of seawater. Salinity is the total quantity (in grams) of solid substances dissolved in 1 kg of seawater. In the oceans it amounts to 35 $^{o}/oo$ on the average (ranging from 30 $^{o}/oo$ in the central part of the Arctic basin to 36 $^{o}/oo$ in tropical regions); in the inland seas it ranges from 2-5 $^{o}/oo$ (Gulf of Finland) /294
up to 400 $^{o}/oo$ (Bay of Kara-Bogaz-Gol). The ratio between the quantities of different ions is practically constant everywhere: in terms of mass (with respect to the total amount of dissolved substances) sodium comprises 30.6%; magnesium--3.7%; calcium--1.2%; potassium--1.1%; chlorine--55%; sulfate--7.7%; bicarbonate--0.4%; and bromine--0.2%. For the relationship between the density of seawater and temperature and salinity see Section 14.5.

The vertical gradient of the hydrological parameter (temperature, salinity, density of seawater) is the change in magnitude of this parameter per meter increase in depth. The layer of discontinuity is the layer of water in which the gradient is large (Table 10.4). The density layer is the density discontinuity layer whose density is such that the buoyancy of a submarine increases with depth (See Section 2.1).

Table 10.4

Characteristics of the intensity of the discontinuity layer of temperature, salinity, and density

Parameter gradient	Intensity of discontinuity layer		
	Low	Moderate	High
Temperature, degrees/m	0.1 - 1.0	1.0 - 5.0	greater than 5.0
Salinity, $^{o}/oo/m$	0.05 - 0.1	0.1 - 1.0	greater than 1.0
Density, $kg \cdot m^{-3}/m$	0.02 - 0.2	0.2 - 1.0	greater than 1.0

The stationary discontinuity layer of temperature and density in the equatorial, tropical, and subtropical zones of the ocean exists between the warm water surface layer and the underlying layer of cold

water flowing from the polar and subpolar regions. In outlying seas it is between the layers of water which constantly fill them and which flows from rivers and through straits. A seasonal temperature and density discontinuity layer occurs with the warming up of the surface layer of water during the spring-summer period; turbulent mixing of the water during storms increases its depth and, as a rule, increases its density. With the convective mixing of water, as a result of the autumn-winter cooling, the equalization of temperature with depth occurs; the density of the discontinuity layer gradually decreases until the layer completely disappears.

Propagation of sound in seawater. For the velocity of propagation of sound see Table 34a and 34b, MT-63. At a temperature of 10°, salinity of 35 ^{0}/oo and atmospheric pressure the velocity of sound is equal to 1490 m/sec. It increases by approximately 3 m/sec with a temperature rise of 1°; by 1 m/sec, with a 1 ^{0}/oo increase in salinity; and by 0.2 m/sec with an increase of 1 kg/cm^2 in hydrostatic pressure. The vertical gradient of the velocity of sound is its increment per unit increase in depth from the surface of the sea (if the velocity of sound increases with depth, the gradient is considered to be positive). The sound beam is the path of propagation of sound waves. /295

Sound attenuation in the sea is determined by absorption and scattering. The intensity I of sound at distance Д from the sound source is:

$$I = I_0 e^{-\gamma Д}. \tag{10.3}$$

where I_0 is the sound intensity at that same distance in the absence of absorption. If distance Д is expressed in km, then for frequencies ranging from 7.5 to 60 kHz, attenuation γ is, in db/km:

$$\gamma = 0.036 f^{1.5}, \tag{10.4}$$

where f is the frequency of oscillations, kHz.

Reverberation (residual vibration) conceals the effective signal received when the sonar operates in the listening mode. It is caused by the scattering of sound. The volumetric reverberation is caused by bubbles of gas suspended in the water, by solid particles and by plankton (its intensity is inversely proportional to the square of the distance from the source). Surface reverberation is produced by sea waves (its intensity is inversely proportional to the cube of the distance); and bottom reverberation--by the bottom of the sea (inversely proportional to the fourth degree of distance).

Sound energy losses during reflection at the interface of two media depend on the slip angle θ (the angle between the reflecting surface and the incident sound beam). For small slip angles they are not very great.

During reflections from the bottom of the sea, with θ = 30° and a sandy bottom, the losses reach 50% and from a silty bottom--80%. During reflections from the surface of the sea with θ = 8° and waves 20 cm in height, losses are 30%, and with an increase in wave height and slip angle, energy losses increase.

The sound velocity discontinuity layer is the layer of water in which the gradient of the velocity of sound is large; it usually coincides with the temperature discontinuity layer and, less often, with the salinity discontinuity layer. Some sound waves are reflected from the discontinuity layer and some of them pass through it attenuated in the process. The accumulation of plankton which is frequently found in the discontinuity layer increases the scattering and absorption of sound. Sound waves approaching the discontinuity layer at small slip angles from an area where the sound velocity is lower, undergo complete reflection within the layer and cannot pass through it (Fig. 10.6). /296

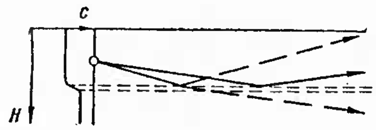

Fig. 10.6. Path of sound beams in the discontinuity layer

Refraction is the bending of sound beams in the direction where the velocity of sound is the lower. The zone of acoustic illumination is the region in the water to which sound waves pass directly from the sound source; the penumbra zone is a region where they arrive attenuated after passing through the layer of discontinuity of after reflecting from the surface or bottom of the sea; the umbra zone is the region where the sound waves do not penetrate at all. The formation of umbra and penumbra zones for sonar equipment with the directivity in the vertical plane is shown in Fig. 10.7 for various sound wave propagation conditions (on the left there are graphs which show the variation in the velocity of sound with depth and on the right there is the path of the sound beams; the acoustic penumbra zone is indicated by the single shading and the umbra zone by the double shading). The underwater sound channel (Fig. 10.7d) occurs when, at a certain depth, the velocity of sound has a minimum. When propagating in the channel the sound waves undergo the total internal reflection, a fact which makes the attenuation negligible and creates conditions for superlong range propagation of sound (up to several thousand miles).

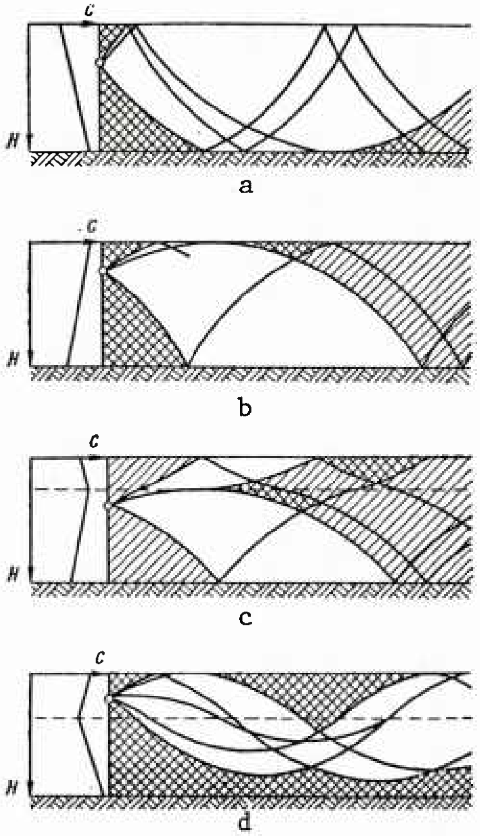

Fig. 10.7. Propagation of sound

a - with an increase in the velocity of sound with depth;
b - with a decrease in the velocity of sound with depth;
c - velocity of sound at a certain depth is maximal;
d - velocity of sound at a certain depth has a minimum (formation of an underwater channel)

Sea ice. The elementary forms of ice are: ice needles, grease ice, new snow, and sludge. Young (glassy) ice includes: pancake ice; glass ice (dark, 3-5 cm in thickness; light, 5-10 cm in thickness); grey ice /297 (10-30 cm in thickness); and white ice (30-70 cm in thickness). In the Arctic seas there are: two-year ice up to 2-2.5 m in thickness and ice of several years' standing (Arctic pack ice) with a thickness of more than 2.5 m. Forms of stationary ice: young shore ice (width up to 200 m); land floe (width up to several hundred kilometers); stamukh (the piling up of grounded hummocky ice). Floating (drift) ice: ice fields (extensive, more than 10 km in diameter; large fields, from 2 to 10 km; small fields, from 0.5 to 2 km; field fragments, from 100 to 500 m); broken ice (large fragments, consisting of ice floes 20-100 m

in length; small fragments, consisting of ice floes 2-20 m in length; pieces of ice, 0.5-2 m in size, and crushed ice).

The compaction of ice is the ratio of the area covered by the ice to the total area of the region of the sea under consideration. It is evaluated in points from 0 (no ice) to 10 (the entire visible area of the sea is covered with ice). The scale for trafficability of the ice, in points, is: 0--a ship moves through the open water; 1--a ship moves by changing course slightly and going around large ice floes with relative ease; 2--a ship moves by tacking between ice floes and by occasionally changing speed; 3--a ship moves by plying hard and breaking ice sections connecting individual floes; 4--a ship moves barely steering her course; she breaks up the ice in her path and proceeds very slowly; 5--a ship moves by ramming the ice; 6--attempts to sail through are unsuccessful.

The permissible load produced by the non-hummocky sea ice: 5 cm in thickness--up to 0.1 ton; 10 cm--up to 0.5 ton; 12 cm--up to 0.8 ton; 15 cm--up to 3.5 tons; 20 cm--up to 6 tons; 30 cm--up to 15 tons; and 50 cm--up to 25 tons.

Seaway. The crest of a wave is the highest point of the wave cross-section and the trough is the lowest. The length λ of a wave is the horizontal distance between two adjacent crests or troughs. The height h of a wave is the vertical distance between a trough and a crest. The period t of a wave is the interval of time during which the wave travels a distance equal to its length; the velocity c is the distance the crest travels horizontally in the direction of the movement of the wave per unit time. If λ is in meters, t in seconds, c in m/sec, the basic relationships are:

$$\tau = \sqrt{\frac{2\pi}{g}\lambda} = 0{,}8\sqrt{\lambda}; \qquad (10.5)$$

$$c = \sqrt{\frac{g}{2\pi}\lambda} = 1{,}25\sqrt{\lambda}. \qquad (10.6)$$

The sea state (see Table 50a, MT-63) is the characteristic of the wave height; it is determined from the height of the largest waves and is expressed in points from 0 (no waves) to IX (very high sea; height of waves greater than 11 m). The state of the surface of the sea (see Section 14.6) is a characteristic of the observed appearance of the sea and it is determined by eye from the appearance of the wind waves only (not the sea swell). /299

To every wind velocity value there corresponds the maximum height and length which waves can have in the presence of wind. The minimal

fetch (the distance traveled by the wind over the sea in an almost constant direction with deviations of no more than 45° from the general direction) and the duration of the wind (the time interval between the beginning of wave formation and the time when the waves become maximum for the given wind velocity) are presented in Table 10.5. With an increase in fetch and wind duration above these minimal values the height of the waves does not increase while the length may increase slightly (the swell of the sea is superimposed on the wind waves). /300

Table 10.5

Relationship between wave elements and wind velocity, duration and fetch (according to L. F. Titov)

Wind			Maximal wave elements (with a 5% assurance)			
Velocity, m/sec	Fetch, miles	Period, hrs.	Height, m	Length m	Period, sec	h/λ
6	32	4.6	1.1	13	3.0	1/12
9	72	7.2	2.2	30	4.4	1/14
11	110	8.9	3.0	45	5.4	1/15
14	182	11.7	4.6	72	6.8	1/15
17	275	14.5	6.4	108	8.3	1/17
20	385	17.3	8.4	149	9.8	1/18
23	523	20.2	10.7	197	11.2	1/19
27	725	24.1	14.0	272	13.2	1/19
30	905	27.0	16.8	336	14.7	1/20

Note: Assurance of 5% means that, on the average, 5% of the waves have dimensions somewhat greater than those indicated in Table 10.5.

Currents. See Section 7.2, Subsection 3.

Tidal variations of the sea level. The zero depth (Fig. 10.8) is an arbitrarily selected surface from which one reads the sea depths which are marked on nautical charts and the sea levels which are given in manuals on tides.

In the USSR for seas without tides one uses the mean level of the sea and with the tides--the theoretical zero depth. The height h of a tide (the height of the tidal level) is the height of the instantaneous level of the sea at a certain time above the zero depth. The depth

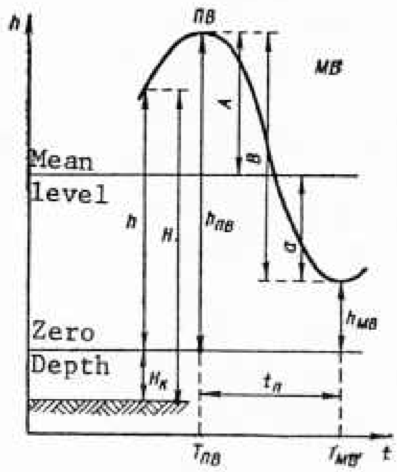

Fig. 10.8. Designations used with the tides

from the surface to the bottom of the sea at this instant is:

$$H = H_K + h, \tag{10.7}$$

where H_K is the sea depth shown on the chart.

High water (ПВ) is the highest sea level occurring during a flood tide. Low water (MB) is the lowest sea level occurring during an ebb tide. The high (low) water observed before local noon is the morning tide; after noon--the evening tide. The high-level high water is the high water observed in the course of 24 hours in the presence of which the level of the sea rises and the low-level high water is when the level of the sea drops. High- and low-level low water is defined similarly.

The high (low) water time $T_{ПВ}$ (T_{MB}) is the time when the high (low) tide occurs. The height of the high (low) water, $h_{ПВ}(h_{MB})$, is the height of the tide at this time.

The tidal range B is the difference in heights between consecutive high and low waters (it is large between the high-level high water and low-level low water and small between the low-level high water and the high-level low water). The amplitude of a tide is the absolute value of the difference in height between the high (low) water and the mean sea level (the large amplitude A is determined from the height of the high-level high water or low-level low water; the small amplitude a--from the height of the low-level high water or high-level low water).

A lunar day is the time interval between two consecutive lower

culminations of the moon. The duration t_p of the sea level increase is the interval of time between the low water and the next high water; the duration t_Π of the sea level decrease is the time interval between the high water and the next low water. The diurnal inequality, in terms of the height of the tide, is the difference between two high (low) waters /301 observed in the course of a lunar day and, in terms of time, it is the difference $(t_p - t_\Pi)$.

Semidiurnal tides. In the course of a lunar day there are two high and two low tides (regular tides occur when the diurnal inequalities in height and time are negligible and irregular tides when the diurnal inequalities are great). Diurnal tides. In the course of a lunar day one high and one low tide is observed.

Spring tides are observed around the time of the new and full moons and neap tides occur when the moon is in the first or third quarter (the amplitudes of spring tides are greater than those of neap tides). Equatorial tides are observed when the declination of the moon is close to zero and tropical tides are tides occurring at the time of the maximum declination of the moon (during tropical tides the inequalities of the tides in terms of time and height increase).

Calculation of tides aboard ships is performed by using the annual /302 Tide Tables: Volume I covers waters of the European part of the USSR Volume II--waters of the Asian part of the USSR; Volume III--foreign waters, the Atlantic, Indian and Arctic Oceans; and Volume IV covers the Pacific Ocean. The time of occurrence and the heights of the high and low tides at major locations are obtained from Part I of the appropriate volume of Tables by using the name of the location and date or, from the constant Tide Tables, by using the name of the location and the astronomical parameters N and C. These parameters are the same for all points; they are obtained from the tables Astronomical Parameters N and C for the Years ... to ... covering several years. In using the tide tables it should be kept in mind that they give the time according to the time zone in which the major location is, without giving the standard time.

Tides at secondary locations are calculated with the aid of Part II of the appropriate volume of Tables. From the name of the secondary location one obtains the time corrections for high and low tides (after adding the time correction to the time of the high or low tide at the major location, the time of the high or low tide at the secondary location is obtained). Using the height tables, one obtains the height at the high (low) tide at the secondary location from the height of the high (low) tide at the major location. When these calculations have been performed, the height of a tide at any given time can be calculated with the aid of the interpolation tables contained in each volume of the tide tables.

CHAPTER 11

SHIP COMMUNICATION SYSTEMS AND REGULATIONS GOVERNING THEIR USE

Section 11.1. Use of Radio Communication in Special Cases According to International Rules

1. Signals of Special Importance /303

An alarm signal is used to alert all radio stations to the forthcoming signal transmission and to notify them of distress or to give cyclone (typhoon) warnings.

A distress signal is transmitted only in those cases when an unavoidable disaster is threatening the ship and her crew and when the ship is requesting assistance.* The distress message contains the name

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* In peacetime warships use international distress signals only when sailing alone and when assistance cannot be rendered by their own warships and vessels.

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of the ship in distress, her coordinates, the nature of the distress, type of assistance required and any other information that would facilitate the rendering of assistance. When proceeding to render assistance the ship should transmit to the vessel in distress her name, location, and speed.

An urgency signal is transmitted when a vessel is not threatened with an immediate disaster but when some type of accident has occurred which the crew cannot handle through their own efforts. An urgency signal may be transmitted when there is an urgent message dealing with the safety of another vessel, aircraft, water craft, or people visible from aboard ship. Such cases include accidents aboard ship transmitting the message, accidents involving vessels or aircraft visible from aboard ship, serious illness of a crew member and the need to obtain medical advice, man overboard and the inability of the ship to render assistance.

A safety signal announces that the given radio station will transmit a message about the safety of navigation. The captain of each ship that has encountered dangerous ice, hazardous floating objects, or any other immediate navigational danger or tropical storm, or if the ship ran into a gale wind with the air temperature below zero, /304

resulting in the heavy icing of her superstructures, or if the ship ran into a wind of 10 points or more without receiving a storm warning, should use all means at his disposal to transmit this information to all nearby vessels as well as to shore radio stations.

2. Procedure for Transmitting Signals of Special Importance

A radiotelegraph alarm signal consists of 12 four-second dashes, each sent at one second intervals. It is transmitted by the automatically operating alarm signal transmitters or by telegraph keys controlled by a stop watch.

A radiotelephone alarm signal consists of two sinusoidal tone signals with frequencies of 2200 and 1300 Hz transmitted alternately in the course of one minute. The length of each tone signal is 250 microseconds.

A radiotelegraph distress signal consists of the SOS group transmitted in the form of a single sign and, as a rule, immediately after the alarm signal. A radiotelegraph distress call consists of an SOS distress signal repeated three times, letters DE, and of the call signal of the ship radio station or of the name of the vessel in distress repeated three times.

A radiotelephone distress signal consists of the word MAYDAY, the word ISI or THIS IS or DE, pronounced DELTA ECHO, and the call signal or name of the vessel in distress repeated three times. The distress call is transmitted for the purpose of drawing general attention and is not addressed to any specific radio station.

A radiotelegraph urgency signal consists of three repetitions of the letter group XXX (bbb) transmitted with sufficient time intervals between letters and groups.

A radiotelephone urgency signal consists of three repetitions of the word PAN. An urgency signal is addressed to a specific radio sta- /305
tion and is transmitted before calling the station.

A radiotelegraph safety signal consists of three repetitions of the letter group TTT transmitted with sufficient time intervals between letters and groups.

A radiotelephone safety signal consists of three repetitions of the word SECURITE. The safety signal is not addressed to any specific radio station and is directed to all ship radio stations and is transmitted before calling any of them.

The distress and rescue signals are presented in Annexes 9 and 10.

3. International Radio Frequencies for Transmitting Signals of Special Importance

A frequency of 500 kHz is the frequency for transmitting call signals. It is also used in the radiotelegraph mode of operation for transmitting the following:

- alarm and distress signals as well as distress messages;

- urgency and safety signals and messages;

- call signals, answering signals (for ship radio stations) and for transmitting signals indicating the switching to the operating frequencies prior to the exchange of messages.

All ship radio stations as well as shore stations on the medium wave-length watch should audio monitor the 500 kHz calling and distress frequency signals between the 15th and the 18th and between the 45th and the 48th minute of each hour of their watch (periods of radio silence) and stop all transmissions with the exception of those associated with distress, urgency, and safety signals. During these time intervals all transmissions in the 485 to 515 kHz frequency range are prohibited. Ship radio stations conducting radio message exchanges during this time in the short-wavelength range must have a receiver tuned to 500 kHz or have an automatic alarm signal receiver turned on.

A frequency of 2182 kHz is the frequency for transmitting call signals and radiotelephone distress signals. It is used for calling to obtain an answer to earlier calls, for transmitting messages concerning the transfer to the operating frequency, for exchanging messages in the event of distress, and for transmitting urgency and safety signals and messages. All ship radiotelephone stations operating in the intermediate frequency band must ensure ship audio monitoring at a frequency of /306
2182 kHz between zero and the third and between the 30th and the 33rd minute of each hour of their watch. During these time intervals all transmissions with the exception of distress, urgency, and safety signals are prohibited in the 2173 to 2195 kHz frequency band.

A frequency of 156.8 mHz is the international frequency for calling, answering and, if required, transmitting alarm, distress, urgency, and safety signals and distress messages. All other transmissions in the 156.725 to 156.875 mHz band are prohibited.

4. Special Radio Transmissions

Weather radio transmissions include weather forecasts of storms and cyclones, ice warnings and observations, meteorological observations

and reports.

Cyclone warnings and other especially important messages are transmitted to other vessels and to the nearest shore radio stations. They are preceded by the transmission of the safety signal at distress frequencies (500 and 2182 kHz) or at one of the frequencies which may be used in case of distress.

The ship radio station must obtain instructions from the Commanding Officer indicating which weather report should be received in the given area of navigation. Warnings, weather forecasts and weather reports are usually transmitted by radio stations according to a certain schedule and at specific frequencies. The procedure, frequencies, and schedules of these transmissions by Soviet and foreign shore stations are presented in the Schedules for the Transmission of Weather Information and Navigational Notices to Mariners.

The transmission of navigational notices and warnings to mariners. Warnings about floating objects, icebergs, reefs, about changes in the navigational situation, etc., are transmitted to ships in order to insure safety of navigation. Routine notices are transmitted according to the schedules and procedure for transmissions presented in Provisions for Navigational Information. Special notices are transmitted by radio stations at 500 kHz, preceded by the transmission of the safety signal.

Information of general nature is transmitted by shore stations /307
according to certain schedules and at certain frequencies given in the International List of Radio Identification Stations and Special Services. The ship radio station must provide for the reception of navigational notices, with the instructions concerning the reception of routine notices from specific shore stations issued by the Commanding Officer of the ship.

Time signals are transmitted by radio stations to determine corrections for ship chronometers and to check watches according to schedules and at frequencies given in the International List of Radio Identification Stations and Special Services. Ship and shore radio stations should receive time signal transmissions in order to check their watches at least twice a day. Radio stations which are unable to receive the time signals from the radio stations published in the International List of Radio Identification Stations and Special Services may receive the time signals transmitted by radio broadcast stations.

Section 11.2. Visual Communication and Signalling and the Procedure for Their Use

1. General Considerations

Visual communication and signalling are carried out by means of objects (signal flags, signal shapes, hand flags), lights (signal lanterns, searchlights and yardarm blinkers) and pyrotechnics (flares and marine star shells). As a rule, the ship answers the call by using the same visual communications which was used in calling her.

Texts of orders, reports, and notices compiled from codes for transmission by means of visual communication systems are called signals, while those transmitted as plain texts are called semaphores. A semaphore (signal) transmitted from a ship (station) is called an outgoing semaphore; a semaphore received by a ship (station) is an incoming semaphore; and that received by a ship for transmission to another ship (station) is called a relay semaphore.

Each semaphore is recorded on standard forms and is signed by the sender. A four-digit number indicating the hour and minutes the semaphore was signed is placed after the signature. When the ship is underway or at anchor, all semaphores (or signals) to be transmitted by visual communication systems are sent to the Officer of the Watch and, when the ship is moored to a pier--to the Officer of the Deck. Depending on the address, signals may be classified: /308

- general signals; they are directed to all ships in the formation or to all ships and lookout and communication stations located within the visibility range of the hoisted (transmitted) signals;

-specific signals; they are directed to the individual formation or to the lookout and communication ship or station.

As a rule, the general signal is hoisted (transmitted) by the lookout and communication ship or station without hoisting call signs. In light signalling the general signal is preceded by the general call sign. The general signal is received by all ships in the formation or by all the lookout and communication ships and stations located within the visibility range of the transmitting ship; all lookout and communication ships and stations answer the general signal.

The specific signal is hoisted (transmitted) with the call sign of the ship formation or of the lookout and communication ship or station to which it is directed. This signal is answered by the flagship of the formation, or by the lookout and communication ship or station.

2. Flag Signalling

Signal flags hoisted in one combination or another constitute a flag signal that may include one or several flag signal combinations. The latter can be one-flag, two-flag, three-flag, or four-flag combinations.

For convenience and to shorten the time used in the exchange of messages by means of visual communication and signalling systems, signal codes are used making it possible to partially or completely replace the text of a message with individual signals having the same textual meaning. Special signal codes (see front flyleaf) as well as the Minor Landing Craft and Boats' Signal Book are used in the Soviet Navy. The International Code of Signals is used in the communication with foreign ships, vessels of the USSR Merchant Marine, and of the Ministry of the /309 Fishing Industry.

To transmit any order, instruction, report, or message the appropriate text is located in the signal codes; the signal combinations next to the text are recorded and made up of the signal flags and then hoisted on the halyards. The signalman on the receiving ship (station) records these signal combinations and locates their meaning in the signal codes.

The flag signal range depends on visibility conditions, the height to which the flags are hoisted, their size, and the force and direction of the wind. With good visibility the range is 4-5 miles.

Hoisting the flag signals of a single-flag code. The basic requirement of flag signalling is to insure the visibility of signals. Therefore, flag signals may be hoisted on any yardarm or masthead, provided the sequence established for hoisting individual combinations is observed. It is preferable to hoist the signals so that their position would facilitate rapid interpretation or would indicate the direction of the action or movement specified by the signal. For example, even though one may hoist signals P and L on any yardarm (i.e. port or starboard), they are, as a rule, hoisted on the yardarm corresponding to the direction in which the ship is turning.

Procedure for transmitting signals by means of flags. Code signals, with the exception of those indicating ship's activity, are transmitted by means of flag signals in the following manner:

a) the flagship transmits the signals throughout the formation without displaying the call signs of the addressee and sender; all ships in the formation repeat these signals with flags;

b) the flagship transmits the signals directed to one or several ships only with the call signs of the addressee (addressees); the ships

which are stationed at the shortest distance between the sender and the addressee repeat these signals with flags;

c) ships in the formation transmit signals directed to one ship (including the flagship) or several ships with the call signs of the addressee and sender; these signals are repeated with flags by the ships stationed at the shortest distance between the sender and addressee;

d) ships in the formation transmit signals, constituting a report /310
to the flagship and, at the same time, an announcement to other ships in the formation, with only their own call signs; all ships in the formation repeat these signals with flags.

The flagship has the right to answer the signals indicated in "c" and "d" with an "answering pennant."

Procedure for transmitting signals indicating the activity of a ship. Signals indicating the activity of a ship are transmitted without the call signs of the sender and are not repeated.

The repetition of a signal by means of flags is carried out in the following sequence:

- the sending ship hoists a signal close up;

- ships repeating the signal hoist it half way up;

- the addressee ship hoists the signal close up; following this, the ships repeating the signal also hoist it close up.

The signal is lowered by all ships following the action of the flagship.

Call signs. Every ship, formation of ships, auxiliary vessel, lookout and communications station, and official have call signs assigned which indicate the name of the ship, formation, station, etc., and which are designated by means of special signal combinations. The call signs are used to indicate an address, signature, or they have a special meaning given below. The call signs of a ship (station) to which a signal is addressed constitute the first signal combination.

A ship should hoist (transmit) its call sign:

- upon entering a roadstead (harbor);

- upon leaving a roadstead (harbor);

- when in sight of a lookout and communication station;

- when meeting other ships at sea;

- when ready to carry out an order received or a mission assigned.

Procedure for hoisting call signs:

- the subordinate (or junior officer) hoists (transmits) his call sign to his commanding officer (or senior officer) first;

- the lower-ranking ship hoists (transmits) her call sign ot the higher-ranking ship first; /311

- ships within sight of the lookout and communications stations display (transmit) their call signs first regardless of the rank or of the official's flag carried by the ship.

When it is impossible to determine the rank, the ship entering a harbor displays (transmits) her call sign first. When meeting at sea the procedure is to follow regulations established for the fleet. When ships are sailing in formation, only the flagship displays (transmits) call signs and answers call signs by displaying (transmitting) the call sign of the formation. When a ship is sailing alone and carrying the pennant (broad pennant) of the Commander of the formation the call sign of the formation's Commander is displayed (transmitted). When anchored in a harbor only the senior officer in the harbor answers the call sign of an entering ship.

Call signs hoisted (transmitted) by the flagship to a subordinate ship signify: "You are not doing it right" or "Look around". The call signs are answered with call signs.

3. Light Signalling

Light signalling devices are divided into two groups: directional and nondirectional. Nondirectional devices such as yardarm blinkers may be used when there is no danger of detection (when anchored at the base or in a sheltered harbor). Directional devices are used for signalling, both while at anchor and underway, when secrecy of communication must be maintained.

The transmission with the aid of light communication equipment (Table 11.1) includes calling, exchange of call signs, text, and the end-of-message sign. The communication procedure is as follows:

1. Calling. It consists of the transmission of the "General call" signal or call sign of the ship (or the lookout and communications station). The receiving ship answers the call with an answering signal;

Table 11.1

Telegraph alphabet signs

1. Letters

А · —	Л · — · ·	Ц — · — ·
Б — · · ·	М — —	Ч — — — ·
В · — —	Н — ·	Ш — — — —
Г — — ·	О — — —	Щ — — · —
Д — · ·	П · — — ·	Ъ · — — · — ·
Е ·	Р · — ·	Ы — · — —
Ж · · · —	С · · ·	Ь — · · —
З — — · ·	Т —	Э · · · — · · ·
И · ·	У · · —	Ю · · — —
Й · — — —	Ф · · — ·	Я · — · —
К — · —	Х · · · ·	

2. Numerals

1 · — — — —	5 · · · · ·	9 — — — — ·
2 · · — — —	6 — · · · ·	0 — — — — —
3 · · · — —	7 — — · · ·	
4 · · · · —	8 — — — · ·	

3. Special and supplementary signs

North — · — — —
South — — · · — · ·
East — — — · · · —
West · — — · · · ·
Executive — — · · —
Interrogative · · — — · ·
Telegraph — · · — · ·
Boat — — — — · — · ·
Air · — — — — —
Gas — — · — — · ·
Smoke — · · — —
Jack (flag) — — · · · — —
Cone — · — — — —
1st supplementary sign · · — · ·
2nd supplementary sign · — — — ·
3rd supplementary sign · — — · ·
4th supplementary sign · · · · — — · ·

4. Procedure signs

Sign of the Naval Signal Code · · — — ·
Sign of the Boat Signal Book — — — — · — · ·
Code Sign — · · — · · —
Separation Sign — · · · —

2. Exchange of call signs. The transmitting ship sends DE and then her own call sign or name. The call sign or name is repeated by the receiving ship which then transmits her own call sign or name. In turn, the transmitting ship repeats the call sign or name of the receiving ship;

3. Text. It consists of letter combinations taken from the codes /312
or of words in the text. The reception of each word or group of words is confirmed by the receiving ship with an answering signal. When transmitting letter combinations of number groups of text, following the completion of the general call or call sign, one of the following procedure signs is sent:

Navy Signal Code sign (··---·), indicating that the signal consists of the naval code combinations;

Boat Signal Book sign (----·-··), indicating that the signal consists of combinations taken from the Boat Signal Book;

Coded sign (-··-··-), indicating that the message consists of coded groups.

When transmitting letter combinations or number groups a separation sign (-···-) is transmitted in order to set one combination apart from another.

The end of message consists of the signal $\overline{AR}$ which the receiving ship answers with the letter R.

The exchange of call signs does not have to be made if the ships have already established communication and have exchanged signals.

A diagram showing the transmission of a semaphore (signal) with the aid of the light signalling equipment is presented in Table 11.2.

Procedure Signals

The general call signal (or calling of an unknown ship) is $\overline{AA}$ $\overline{AA}$ $\overline{AA}$, etc. It is transmitted in order to draw the attention of ships which are located within the signal visibility range and whose call signs and names are unknown. Calling continues until the answer from the ship (or the lookout and communication station) is received.

The answering signal is $\overline{TTTT}$, etc. It serves as an answer to calling and is repeated until the calling ship stops calling.

To confirm the reception of each word or group the letter T is used.

Table 11.2 /315

Diagram for the transmission of a semaphore (signal) by means of light signalling devices

Communication elements	Meaning of transmitting ship signals	Sequence in using communication elements	Meaning of receiving ship signals
Calling	General call or call sign of addressee	$\overline{AA}$ $\overline{AA}$ $\overline{AA}$	
		$\overline{TTTT}$ etc.	Answering signal
Exchange of call signs	OT and your own call sign	DE and call sign of transmitting ship	
		Call sign of transmitting ship Call sign of receiving ship	Repeat call sign of transmitting ship and own call sign
	Repeats call sign of receiving ship	Call sign of receiving ship	
Text	Message text from first to last word	Text	
		T	Answering signal for each word received
End of message	End signal	$\overline{AR}$	
		R	I received your last signal

Note: A correctly received combination, signal or word is confirmed (after repeating it) by the OK signal.

The error signal is $\overline{\text{EEEE}}$, etc. It is used to indicate that the last group or word was transmitted incorrectly. The receiving ship answers with the same error signal. Upon reception of an answer the transmitting ship repeats the last correctly transmitted word or group of words and continues to transmit the rest of the message.

The repeat signal (RPT) is used: /314

a) by the transmitting ship as an indication that she intends to repeat the preceding signal ("I repeat"). If such a repetition does not follow, then the signal is considered to be a request to the receiving ship to repeat the received signal ("Repeat what you have received");

b) by the receiving ship as an inquiry about the repetition of the transmitted signal ("Repeat what you have transmitted");

c) with the special repeat signals AA, AB, VA, VB, and BI which are used by the receiving ship. In each case they are transmitted immediately after the repeat signal RPT.

A correctly repeated signal (word) is confirmed by the signal OK. This signal is used as an affirmative answer signal ("Correct") as well.

The end-of-message signal $\overline{\text{AR}}$ is used to end the transmission. The /316
receiving ship answers with the signal R ("Received" or "I received your last signal"). The procedure signs used with the various visual communication methods are presented in Table 11.3.

4. Procedure for Transmitting Code Signals

When using light signalling, signals of a single-flag code are transmitted by following the same sequence used with flags but without the repeat back and, as a rule, without transmitting the preliminary call signals. Upon receiving the signal, each ship in the formation gives an answering sign. If there was no answering sign transmitted the signal is repeated. Each signal combination is separated from the next by a separation sign.

If the Commander of the formation needs to receive confirmation that the signal has reached the addressee then the word "receipt" is added before the end-of-message sign or interrogation sign. In such a case the addressee sends a receipt for the signal, i.e., his own call sign, which is repeated "Along the line" to the Commander of the formation in the following sequence:

- "along the line": To the Commanding Officer...;
- call sign of your own ship;
- end-of-message sign.

On signals transmitted in answer to the execute signal, the rear ships send the flagship a receipt, i.e., their own call signs which are transmitted in the same manner as the signal. Upon their reception the flagship and the rest of the ships turn on a red yardarm blinker. After switching off the red blinker by the flagship all other ships do the same.

Two-flag and three-flag code signals are transmitted in the same way as single-flag signals. However, before transmitting these signals the naval code sign is given and, after each signal combination, a separation sign is transmitted.

Table 11.3 /317

Procedure signals used with various visual communication methods

Signal	Meaning of signal
A**	Negative signal ("No") or "The meaning of the preceding group must be read in the negative form." It is a negative answer to a question.
AA	"Everything after ...", transmitted by the receiving ship immediately after the repeat signal RPT, indicates "Repeat everything after ...".
$\overline{AAA}$	Period (punctuation mark) or decimal point
$\overline{AA}$ $\overline{AA}$ $\overline{AA}$ etc.	General call signal (or calling of an unknown ship). It is transmitted to draw the attention of ships which are situated within the visibility range of signals and whose call signs or names are unknown. Calling continues until the answer from the ship (or the lookout and communication station) is received.
AB	"Everything up to ...", transmitted by the receiving ship immediately after the repeat signal RPT, indicates "Repeat everything up to ...".
$\overline{AR}$	End of message signal. It indicates the end of the transmission of the semaphore or signal.
$\overline{AS}$	Break signal. It indicates that transmission or reception has ceased for a while.
BN	"Everything between ... and ...", transmitted by the receiving ship immediately after the repeat signal RPT,

Table 11.3 (continued)

Signal	Meaning of signal
	indicates "Repeat everything between ... and ...".
VA	"Word or group after ...", transmitted by the receiving ship immediately after the repeat signal RPT, indicates "Repeat the word or group after ...".
VB	"Word or group before ...", transmitted by the receiving ship immediately after the repeat signal RPT, indicates "Repeat the word or group before ...".
GA**	The "execute" signal or "execute" light (red blinker) in closed roadsteads is transmitted immediately after the signal (or semaphore) requiring the simultaneous execution of an order. When the red blinker (or lantern) is turned on, the execute signal indicates "Stand-by" and when it is turned off--"Execute."
D**	Affirmative signal "Yes" or "The meaning of the preceding group must be read in the affirmative form." It is an affirmative answer to a question. /318
DE	"From ...". It is transmitted immediately before the name or call sign of the calling ship.
$\overline{\text{EEEE}}$ etc.	Error signal. It is transmitted by the transmitting ship to indicate that the last word or group has been transmitted incorrectly (by mistake). The receiving ship answers with the same signal, following which the transmitting ship repeats the last word (or group) correctly and continues the transmission.
K	"I want to establish communication with you"; an invitation to begin an exchange of messages.
NR	The number signal "Number" is transmitted immediately after the transmitted text.
OK	Confirmation signal "Correct" or the confirmation of a correctly received repetition. It is an affirmative answer to a question.
R	"Received" or "I received your last signal." It is transmitted by the receiving ship as an answer to the end-of-message signal.

Table 11.3 (continued)

Signal	Meaning of signal
RPT	The repeat signal "I repeat" indicates that the transmitting ship will repeat the preceding signal. If the repetition does not follow, then the signal indicates a request to the receiving ship: "Repeat what you have received." A repeat signal from the receiving ship is considered as the request "Repeat what you have transmitted."
T	The answering signal is transmitted as acknowledgement of the reception of each word or group.
$\overline{\text{TTT}}$ etc.	Signal answering a call signal. It is transmitted until the calling ship stops calling.
TTTT etc., but no less than 10 times	Silence signal. It indicates that all exchanges of messages by means of light communication systems must cease immediately.
F*	The annul signal "Cancel" is transmitted immediately after a general call or call sign, if it is necessary to cancel a semaphore (or signal) just transmitted.
TSS	"What is the name or call sign of your ship or vessel?" it is used by the transmitting ship to request the name or call sign of the receiving ship.
YUI	"Interrogation" signal or "The meaning of the preceding group must be read as a question."

Remarks:

1. The line above the letters forming a signal indicates that these letters should be transmitted as a unit (as one sign).
2. A signal marked by an asterisk (*) is used only in flag signalling with ships of the USSR Navy.
3. Signals marked by two asterisks (**) are used only in light signalling with ships of the USSR Navy.

5. Signalling by Semaphore

A flag semaphore is a system for visual communication and signalling at short distances during the daylight hours (see back flyleaf).

The range of communication with a flag semaphore in good visibility is 1-1.5 miles when receiving messages with the naked eye, and 2.5 miles or more when using optical equipment. The rate of exchange at short distances reaches 100-110 signs per minute; with an increase in distance the rate decreases to 60-70 signs per minute.

The transmission (or reception) of a semaphore or signal is performed in the sequence indicated in Table 11.4.

Table 11.4 /320

Sequence used in the transmission (reception) of semaphores

Actions of the transmitting ship	Actions of the receiving ship
1. Call sign (if there is no answer within 2 minutes, then hoist the name/number pennants to half mast	1. Answering sign (or hoisting of the "Answering pennant" close up)
2. First word of plain text (first signal combination and separation sign)	2. Answering sign (if the word was not understood, hoist the repeat sign or lower the "Answering pennant" to half mast)
3. If the repeat sign is received from the receiving ship (or "Answering pennant" lowered to half mast), then the first word or signal combination is repeated	3. Answering sign (or "Answering pennant") close up
4. If the answering sign is received from the receiving ship, then the second word (second signal combination and separation sign) is transmitted, etc.	4. Answering sign (or if the word was not understood hoist the repeat sign or lower the "Answering pennant" to half mast), etc.
5. Signature	5. Answering sign (or "Answering pennant") close up
6. Semaphore number	6. Answering sign (or "Answering pennant") close up
7. End of message sign (if an answer is not required) or interrogation sign (if an answer is expected)	7. End of message sign (or lowering of the "Answering pennant") in the first case or answering sign if a question was transmitted

6. Pyrotechnic Signalling

Pyrotechnic signalling devices include the following:

- daytime rockets;
- nighttime rockets;
- illumination flares;
- marine star shells.

The meanings of pyrotechnic signals are given in special signal tables and they do not depend on the side of the ship from which a rocket is fired or on its direction. The procedure for repeating pyrotechnic signals is established by special instructions in each individual case. Pyrotechnic signals are transmitted and repeated on order of the Officer of the Watch. The transmission (reception) of each pyrotechnic signal must be recorded in the signal record book.

7. Visual Communication Between the USSR Navy Ships and Vessels of the Ministry of Merchant Marine and the Ministry of the Fishing Industry of the USSR

Soviet Navy ships carry out visual communication with vessels of the Ministry of Merchant Marine and the Ministry of the Fishing Industry of the USSR according to the rules given in the International Code of Signals:

- by means of flag semaphores, using the regular text, Russian semaphore alphabet and observing the rules given in Chapter IX of the International Code of Signals; and

- by means of light signals, using the regular text, Russian telegraph alphabet and observing the rules and procedure signs given in Chapter VI of the International Code of Signals. /321

Section 11.3. The International Code of Signals

1. Purpose of the International Code of Signals

The International Code of Signals is intended primarily for communication with foreign ships and vessels under circumstances arising from the need to insure the safety of navigation and safety of life at sea, especially in those cases where language communication difficulties exist. The code permits signalling using all communication methods, including radiotelegraph and radiotelephone. It is based on

the principle that each signal has a specific meaning. In individual cases numerical supplements are used to expand the meaning of the basic signal.

2. Flag Signalling Using the International Code of Signals

As a rule only one flag signal should be hoisted at one time. Each signal or a group of signals must remain hoisted until the appearance of the answering signal on the receiving ship (vessel).

Calling a vessel. The call signs of a ship being called should be hoisted simultaneously with the signal on a separate halyard. If the call signs are not hoisted, then it indicates that the signal is addressed to all ships within the signal visibility range. If it is impossible to determine the call signs of the vessel to which a signal must be transmitted, then the VF signal "You should hoist your call sign" or the CS signal "What is the name or call sign of your vessel?" should be hoisted first. At the same time the transmitting vessel hoists its own call sign.

Answering a signal. All vessels to which signals are addressed or which are mentioned in the signals, must hoist the "Answering pennant" to half-mast as soon as they see them. Immediately after the interpret- the signal the "Answering pennant" should be hoisted close up and lowered to half mast as soon as the transmitting station hauls down the signal. It must be hoisted close up once again following the interpretation of the next signal.

Ending a signal exchange. After hauling down the last flag signal the /322
transmitting ship must hoist an "Answering pennant," indicating that this is the last signal. The receiving vessel must answer this signal just as it does all other flag signals.

Action to be taken if a signal is not understood. If the receiving vessel cannot make out a signal transmitted to it, then it must keep the "Answering pennant" displayed at half mast. If the signal is distinct but its meaning is not clear, then the receiving vessel can hoist the following signal: ZQ--"Your signal is apparently encoded incorrectly. You should check and repeat the entire signal" or ZL--"Your signal was received but not understood."

The use of substituting pennants. The use of substituting pennants makes it possible to repeat the same letter flag or number pennant once or several times in the same group, if there is only one set of signalling flags aboard ship. The first substituting pennant always repeats the topmost signalling flag (No. 1) of the first signal combination; the second substituting pennant repeats the second (No. 2) and the third

(No. 3) signalling flag from the top. The substituting pennant can never be used more than once in the same group. The "Answering pennant," when used as a decimal sign, must not be taken into account in determining which substituting pennant should be used.

Transmission of letters. The names of vessels or geographical places in the text of a flag signal should be transmitted letter by letter using the Latin alphabet.

Single-letter signals. For convenience and to shorten the time of the exchange of very important messages when using visual communication and signalling equipment, the International Code of Signals provides single-letter signals. These signals can be transmitted by any communication method.

3. Light Signalling Using the International Code of Signals

A signal transmitted by means of light signalling equipment using the International (Latin) Morse alphabet (Table 11.5) includes the following elements:

1. Calling. It consists of the general call signal or call sign /324
of the vessel being called; the vessel responds with an answering signal;

2. Recognition. The transmitting ship transmits DE and then her own call sign or name. These signals are repeated by the receiving ship which then transmits her own call sign or name. The transmitting ship in turn repeats the call sign or name of the receiving ship;

3. Text. It consists of the International Code Signal groups of words or words of regular text. The transmission of groups of words must be preceded by the signal YU--"I intend to establish communication with your vessel by means of the International Code of Signals." Words in open text may also be included in the signal containing names, titles, etc. The reception of each word or group of words is confirmed by the transmission of the letter T.

4. End of message. It consists of the end-of-message signal $\overline{AR}$ which is answered by transmitting the letter R.

If the entire signal is transmitted by means of words in the regular text, then the same procedure is followed. Calling and recognition may be omitted if two stations have already established communication and have exchanged signals. Table 11.6 can be used to transmit the Russian alphabet transliterated with Latin letters.

Table 11.5 /323

Alphabet

A · —	H · · · ·	N — ·	T —
B — · · ·	I · ·	O — — —	U · · —
C — · — ·	J · — — —	P · — — ·	V · · · —
D — · ·	K — · —	Q — — · —	W · — —
E ·	L · — · ·	R · — ·	X — · · —
F · · — ·	M — —	S · · ·	Y — · — —
G — — ·			Z — — · ·

Numerals

1 · — — — —	6 — · · · ·
2 · · — — —	7 — — · · ·
3 · · · — —	8 — — — · ·
4 · · · · —	9 — — — — ·
5 · · · · ·	0 — — — — —

Procedure signals

$\overline{\text{AR}}$ (· — · — ·) — End-of-message signal
$\overline{\text{AS}}$ (· — · · ·) — Break or separation signal

$\overline{\text{AAA}}$ (· — · — · —) — Period (punctuation mark) or decimal point

Light signalling

$\overline{\text{AA}}$ $\overline{\text{AA}}$ $\overline{\text{AA}}$ etc. — Calling an unknown station or the general call signal
$\overline{\text{TTTT}}$ etc. — Answering signal
T — Word or group of words received

$\overline{\text{EEEEEE}}$ etc. — Error signal /324
$\overline{\text{AAA}}$ — Period (punctuation mark) or decimal point

Note: Certain letters such as ë, ä, ö, etc. are not shown, since:
a) they do not have international application;
b) they are contained in local codes;
c) some of them are a combination of two letters.

Table 11.6

Correspondence between
the International and Russian Morse Signs

International	Russian	International	Russian
A	А	N	Н
B	Б	O	О
C	Ц	P	П
D	Д	Q	Щ
E	Е	R	Р
F	Ф	S	С
G	Г	T	Т
H	Х	U	У
I	И	V	Ж
J	Й	W	В
K	К	X	Ь
L	Л	Y	Ы
M	М	Z	З

Russian	International	Russian	International
А	A	Р	R
Б	B	С	S
В	W	Т	T
Г	G	У	U
Д	D	Ф	F
Е	E	Х	H
Ж	V	Ц	C
З	Z	Ч	—
И	I	Ш	—
Й	J	Щ	Q
К	K	Ъ	—
Л	L	Ы	Y
М	M	Ь	X
Н	N	Э	—
О	O	Ю	—
П	P	Я	—

4. Semaphore Signalling

A vessel desiring to communicate with another vessel in the international semaphore system (see back flyleaf) can indicate the desire by transmitting, by any method, the signal K1 (KiLo Unaone)--"I wish to establish communication with you by semaphore." If the vessels are close to another, then instead of this signal the attention sign (call sign) may be transmitted.

Upon reception of the call the ship to which the call is directed /325
must either hoist an answering pennant to half-mast, transmit the answering sign, or, if it is impossible for her to communicate by semaphore, answer with the YS1 signal "I cannot establish communication by semaphore." To indicate readiness to receive, the "Answering pennant" is hoisted close up.

Messages by semaphore must always be transmitted by using the regular text, while the numbers encountered in the semaphore message must always be transmitted as words (spelled out).

After each word the arms of the signalman should be lowered to the position of the space sign. When double letters are encountered the arms should be lowered to the position of the space sign immediately after the first letter and then raised in order to produce the second letter, without pausing. The error sign is indicated by the transmission of a set of letters consisting of the letter E.

The reception of each word is confirmed by the receiving station through the transmission of the answering sign. If this sign is not transmitted the word should be repeated. All messages end with the end-of-message sign $\overline{AR}$. Table 11.7 can be used to convert the international semaphore signs into Russian and vice versa. /326

5. Morse Code Signalling by Means of Semaphore Flags

A vessel desiring to communicate with another vessel in Morse Code by using flags can indicate the desire by transmitting, by any method, the signal K2 (KiLo Bissotwo) "I wish to establish communication with you in Morse code by using semaphore flags." The general call signal $\overline{AA}$ $\overline{AA}$ $\overline{AA}$ may be transmitted instead of signal K2.

Upon reception of the call the ship to which the call is directed, must transmit an answering signal or, if she is unable to communicate by this method, she should transmit by any available system, the YS2 signal "I cannot establish communication by signalling in Morse code using semaphore flags."

The general call signal $\overline{AA}$ $\overline{AA}$ $\overline{AA}$ and the signal T must be used by the transmitting and receiving vessels, respectively. All messages end with the end-of-message sign $\overline{AR}$. /327

Table 11.7

Correspondence between the International and Russian Semaphore Signs

International	Russian	International	Russian
A	Н	N	А
B	В	O	Ю
C	Е, Э	P	Р
D	И, Й	Q	З
E	С	R	Т
F	Г	S	Ц
G	О	T	Щ
H	Б	U	У
I	Х	V	Ф
J	П	W	Я
K	Ы	X	К
L	М	Y	Ж
M	Ч	Z	Д

Russian	International	Russian	International
А	N	Р	P
Б	H	С	E
В	B	Т	R
Г	F	У	U
Д	Z	Ф	V
Е, Э	C	Х	I
Ж	Y	Ц	S
З	Q	Ч	M
И, Й	D	Ш	—
К	X	Щ	T
Л	—	Ъ, Ь	—
М	L	Ы	K
Н	A	Ю	O
О	G	Я	W
П	J		

6. Sound Signalling

In view of the peculiarities of sound-emitting devices (whistles, sirens, fog horns, etc.) the transmission of sound signals proceeds slowly. Taking this into account as well as the fact that the improper use of sound signals can result in serious complications at sea, the use of sound signals in fog must be reduced to a minimum. With the exception of single-letter signals all other signals may be transmitted by sound only in case of extreme urgency and must never be used in waters with heavy traffic.

The signals must be transmitted slowly and distinctly. If necessary they may be repeated but only after rather long time periods in order to preclude the possibility of errors in signalling and to avoid receiving the single-letter signals as two-letter groups of words.

Watch officers must bear in mind that in transmitting single-letter code signals marked with an asterisk (*) sound systems can be used only when the international rules for preventing collisions at sea are observed. This also applies to single-letter signals intended exclusively for use between an icebreaker and escorted ships.

Section 11.4. Regulations Governing Signalling Carried Out in Special Cases

1. Hoisting Flags on Ships

The national ensign of the USSR is displayed on Navy ships:

a) during an official visit aboard ship by the Chairman of the Presidium of the Supreme Soviet of the USSR, the Chairman of the Council of Ministers of the USSR, their deputies and other individuals representing the Supreme Soviet of the USSR, the Presidium of the Supreme Soviet of the USSR, and the Council of Ministers of the USSR--from the fore truck, both underway and at anchor, with the consent of the indicated individuals; /328

b) on 22 April; 1, 2, and 9 May; 7 and 8 November; and on 5 December;

c) during the presentation of government awards to ships (or formations of ships);

d) during holidays and special events not indicated in (b) and (c)--by order of the Minister of Defense of the USSR.

As indicated in (b), (c), and (d) the national ensign of the USSR is displayed from trucks of all masts only when the ship is at anchor (moored).

The USSR naval ensign is displayed on ships underway--from the gaff (or flagstaff) and when anchored (or moored)--from the flagstaff. The hoisting of the ensign on ships at anchor (or moored) is done, both in summer and winter, at 0800 hours on working days; on rest days and holidays--at 0900 hours. The ensign is lowered at sunset. In the polar seas the time for lowering the ensign is set by order of the Commander of the fleet. Ships underway at sea fly the naval ensign day and night, without lowering it.

When going to sea after sunset and before 0800 or 0900 hours, ships hoist the naval ensign at the time of transition from the "at anchor (moored)" to the "underway" condition. If a ship is returning from sea or calling at a port (harbor) during the nighttime or from dawn to 0800 (0900) hours, the ensign on the ship is lowered at the time of transition from the "underway" to the "at anchor (moored)" condition.

When a ship changes station in a roadstead or in a harbor during the nighttime or from dawn to 0800 (0900) hours, the ensign is not hoisted.

If several ships are in a roadstead, the ensign is hoisted or lowered on signal from the roadstead station or from the senior officer in the roadstead.

The hoisting (lowering) of the navy ensign may be ceremonial or regular.

The ceremonial hoisting of the ensign is conducted:

a) on 22 April; 1 and 9 May; 7 November; and 5 December; /329

b) on anniversary days of the Soviet Army (23 February) and Navy; during the presentation of the navy ensign to the ship and its first hoisting on the ship; during annual ship's (formation's) day;

c) on holidays and during celebrations not indicated above--by order of the Commander of the fleet (flotilla).

2. Hoisting and Lowering of the Naval Ensign

Five minutes before the hoisting (or lowering) of the ensign on the ship of the formation Commander or of the Senior Officer at a roadstead, by order of the Officer of the Watch (or on signal from the roadstead lookout and communications station), one "Execute" flag is hoisted to half-mast if the regular hoisting (lowering) of the ensign is about to take place and two "Execute" flags are hoisted on the same halyard for a ceremonial hoisting (lowering) or the ensign. This signal is repeated by the ships under other formation Commanders while the rest

of the ships hoist an "Answering pennant" to half-mast.

One minute before the hoisting (lowering) of the ensign on the ship of the formation Commander or of the Senior Officer at a roadstead (or roadstead lookout and communications station) the "Execute" flag is hoisted close up, on command "The ensign and jack. Attention", with all other ships hoisting "Answering pennants" close up.

At precisely the designated time aboard ship of the formation Commander or of the Senior Officer at a roadstead, on command "Hoist (lower) the ensign (and jack)," the "Execute" flag is lowered and the ensign is hoisted (lowered). Following the flagship, the rest of the ships, after lowering the "Answering pennant," hoist (lower) the naval ensign.

In the polar seas, during the dark hours of the day when the ensign is not visible, a red yardarm blinker, i.e., the "Execute" sign, is turned on five minutes before the hoisting (lowering) of the ensign, instead of hoisting the "Execute" flag to half mast on the ship of the formation Commander or of the Senior Officer at a roadstead (or roadstead lookout and communications station). This sign is repeated by flagships and roadstead lookout and communications stations. After the repetition the red light is turned off.

One minute before hoisting (lowering) the ensign on the ship of the formation Commander or of the Senior Officer at a roadstead (or roadstead lookout and communications station), a red light, i.e., the "Execute" sign, which is repeated by all ships, is turned on. At /330
precisely the designated time of the hoisting (lowering) of the ensign aboard ship of the formation Commander (or roadstead lookout and communications station) the red light is turned off. The rest of the ships also turn off their red lights and hoist (lower) the ensign.

During commissioning of the ship the hoisting of the naval ensign is performed in the ceremonial manner. The naval ensign is presented to the ship by the Commander of the fleet or by an admiral (officer) designated by him. The individual presenting the naval ensign reads the commissioning order and presents the naval ensign and the order to the Commanding officer of the ship. The Commanding Officer parades the naval ensign in front of all hands and then secures it for hoisting on the gaff (or the flagstaff). Upon receiving the order of the individual arriving aboard ship to conduct the ceremony, the formation commander issues a command: "Hoist the naval ensign, jack, masthead flags and dress flags." The procedure for hoisting the ensign is the same as that used in the ceremonial hoisting of the ensign. In this instance the Commanding Officer hoists the navy ensign.

The procedure for presenting ships with the Guard or Order flags and for conducting ceremonies on the occasion of hoisting these flags on ships is the same as that used when commissioning the ship. In

this case the naval ensign is lowered after the Guard or Order flag is hoisted close up.

The ceremonial lowering of the navy ensign is conducted when ships are taken out of service. The Commanding officer of the ship personally hauls down the naval ensign in the presence of the Commander of the formation.

3. Flags of Officials

The flags of high-ranking officials of the Armed Forces of the USSR, including the flag of the Fleet Commander are displayed from the main truck (from the truck if there is one mast). The flags of a Commander of a flotilla, Commander of a squadron or formation of ships are displayed from the fore truck.

The broad pennant of the Commander of a formation is displayed from the main truck (from the truck if there is one mast). At a roadstead the broad pennant of the senior officer is displayed below the flag of an official or below the pennant.

The flags of officials are hoisted on ships where these individuals /331
have official residence. These flags are hoisted and lowered with the permission of the individuals to whom they have been awarded. As the official's flag is hoisted on a ship, this flag, displayed on another ship, is lowered. With the hoisting of the senior official's flag on a ship, the flag of the junior official displayed on that ship is lowered.

The flag (broad pennant) of an official is transferred from one ship to another as follows:

a) as the official arrives aboard ship (or at the designated time), on command "Hoist the flag (broad pennant)," the flag is hoisted unfurled;

b) on command "Lower (such and such) flag," the flag is quickly lowered on the ship where the flag was displayed heretofore, at the time of the hoisting of this flag close up on the other ship.

Commanders of ship formations hoist the flags or broad pennants assigned to them only on ships of their own formations. The procedure for hoisting flags is as follows:

a) on command from the Officer of the Watch to prepare the given flag (broad pennant) for hoisting, the signalman assigned to the halyards, secures the flag unfurled to the proper halyard, checks to make

certain that the halyard is clean, and holds the attached end of the halyard together with the flag in one hand and the running end in the other;

b) on command "Hoist the flag (broad pennant)" the signalman hoists it smoothly close up.

The procedure for lowering the flag is as follows:

a) on command of the Officer of the Watch to prepare for lowering the given flag, the signalman takes the halyard in his hand, cleans it and gets ready to lower the flag (broad pennant);

b) on command "Lower the flag (broad pennant)" the signalman smoothly lowers the flag (broad pennant).

If the Officer of the Watch is far from the site of the hoisting (lowering) of the flag and commands are not given, then the flag (broad pennant) is hoisted (lowered) to answer the previously received order.

The flags and broad pennants of officials remain hoisted day and night as well as during the short temporary absences of the officials to whom they have been assigned.

When officials are traveling in launches (or boats) on official /332
business, the flags (broad pennants) awarded to them are displayed from the foreward flagstaff or mast on their order.

During personal salutes the flag of an official in whose honor the salute is rendered is hoisted on the fore truck. The salute begins with the flag hoisted close up. The flag is not lowered as long as the official is aboard ship. The flag is lowered when the official leaves the ship.

4. Procedure for Hoisting and Lowering Pennants

A pennant indicates that a ship is steaming in company. It is displayed from the main truck (or truck if there is only one mast) of the ships to which naval ensigns have been assigned. The pennant is hoisted and lowered by order of the Commander of the fleet (or flotilla).

The pennant is flown continuously day and night, in any weather, and when the ship is underway or at anchor (moored). It is not displayed if the flag or broad pennant of an official is flown on one of the masts.

The hoisting (lowering) of the pennant can be performed either simultaneously with the hoisting (lowering) of the flag or at specially

designated times.

In the first case a signalman is assigned to the pennant halyard (in addition to signalmen assigned to halyards for the flag and jack) for hoisting (lowering) the pennant. At the prescribed time the Officer of the Watch issues a command: "The ensign, jack, and pennant. Attention." On this command the signalman assigned to the halyard for the pennant secures the pennant unfurled and stands at "Attention". Then, when ready for hoisting (lowering) of the flag, on command "Hoist (lower) the ensign, jack, and pennant" the signalman slowly hoists (lowers) the pennant unfurled. The rate of hoisting (lowering) is regulated so that by the end of the playing of the band (or bugler) the pennant has reached the truck of the mast (or the pennant has been lowered).

In the second case the pennant is hoisted (lowered) on commands: "To the halyards," "Hoist (lower) the pennant."

5. Returning Salutes with a Flag /333

When meeting at sea or sailing past a ship at anchor a merchant vessel of the USSR or a foreign country salutes by lowering her flag to half-mast, then the salute is returned with a flag. The answering salute consists of the following: on command from the Officer of the Watch the signalman, standing by at the halyard, slowly lowers the naval ensign to one-third the length of the flagstaff and then slowly hoists it close up.

For making a timely response to a salute the petty officer of the signal watch sends, without any special command, a signalman to the halyard of the naval ensign. The signalman, taking his station at the halyard, removes the halyard from the cleat and awaits the command of the Officer of the Watch for an answering salute.

6. Hoisting and Lowering Dress Flags

During the ceremonial hoisting of the USSR naval ensign, masthead flags and dress flags are hoisted. Masthead flags are hoisted on all masts, with the flags of officials flown below the masthead flags.

The national ensign of the USSR and the navy ensign are displayed as described in Section 11.4, Subsection 1.

On 2 May and 8 November the national ensign of the USSR and dress flags are hoisted at the time of the regular hoisting of the navy ensign.

The dressing of ships is done by flying flags between the mast trucks and between the masts and the stem and stern post of the ship. Ships, which for technical reasons, cannot be dressed this way may be dressed by flying flags only between the fore truck and the stem.

Triangular flags are displayed between the stem and the fore truck; rectangular flags are displayed between the mast trucks; and triangular and rectangular flags with flies are flown between the truck of the main or mizzen mast and the sternpost. In dressing a ship the following flags are not used:

- the national ensigns of the USSR and Union Republics;

- the naval ensign of the USSR; /334

- the flags of auxiliary ships of the Navy and ships of the border forces of the USSR;

- the jack;

- flags and broad pennants of officials;

- foreign national, military, and merchant marine flags and flags of officials;

- flags which belong to the signal flag set and which carry drawings similar to those shown on foreign national flags. At the present time such flags include B, K, N, R, Kh, Ts, E, the Execute sign, the 3rd supplementary sign, 3, 4, 7, and 9.

The selection of flags for hoisting when dressing a ship should be made so that the flags or their individual signals would not form any phrases or words with their letters. Dress flags are hoisted on halyards especially prepared for this purpose.

On ceremonial occasions the masthead flags and the dress flags are hoisted together with the naval ensign and are hauled down with the lowering of the ensign.

When getting underway dress flags are lowered 30 minutes before the prescribed time of weighing anchor (unmooring). When anchoring a ship (mooring) dress flags are hoisted at the time of hoisting the jack (or transferring the flag).

In bad weather when the ship is at anchor (moored), only the masthead flags are displayed on special occasions. The lowering and hoisting of dress flags with the approach of bad weather is done by following the actions of the senior officer at a roadstead (and when sailing alone--by order).

7. Military Honors with Flags during Burials

A ship on which the body of a deceased person is on board lowers the naval ensign to half-mast and hoists it close up when the body is committed to the sea or when a launch (boat) carrying the body to shore is no less than 2 cable lengths away from the ship.

In addition, during burial of a formation commander, the commander's flag is lowered to half-mast on the flagship. /335

All ships past which a launch or ship with the body of the deceased must pass, lower their stern flags to half-mast when the launch (ship) approaches them at a distance of 2 cable lengths and then hoist them close up when the launch (ship) is at a distance of 2 cable lengths away.

When transporting the body of a formation commander in a launch (or boat) the commander's flag (broad pennant) is displayed at half-mast from the foreward flagstaff.

In wartime flags on ships are not lowered to half-mast.

8. Procedure for Dressing Ships during Visits of Ports and Territorial Waters of Foreign Nations by Soviet Ships

During ceremonial receptions for foreign warships arriving at ports or in waters of the USSR and carrying heads of state or heads of government, the USSR Navy ships that are in the port and assigned for the meeting, are dressed.

When Soviet warships are in foreign ports and participating in the celebration of foreign state holidays, they are dressed with flags. They display the national flag of the celebrating state at the main truck and their own flags at the other trucks.

The procedure for ceremonial hoisting of the naval ensign on ships during their visits abroad is the same as that used in home waters. However, after the completion of the national anthem of the Soviet Union, the band plays the national anthem of the host country and then the anthems of those nations whose ships are participating in the celebration.

When at anchor in a foreign port the naval ensign of the USSR is hoisted (lowered) on Soviet Navy ships at the same time as when sailing in home waters. If local conditions do not permit, the Commander of the formation of ships (or the Commanding Officer of the ship, if sailing alone) may set a different time for hoisting (lowering) of the ensign.

If warships of other states are in a roadstead and if on these ships the Commander of the formation (or of the ship) is senior in rank to the Commander of the formation of Soviet ships (ship), then the Soviet Navy ships follow the actions of the Senior Officer at the roadstead in hoisting and lowering the flag. /336

In saluting a nation the saluting ship hoists the national flag of the nation in honor of which the salute is given, to the main truck. The flag unfurled is hoisted slowly. The salute begins when the flag reaches the top. Upon completion of the salute the flag is lowered to the masthead slowly and then quickly.

During gun salutes to members of the USSR government the national ensign of the USSR is displayed, and to Soviet officials, the official flag assigned to them. The national flag of the USSR is displayed for Soviet officials to whom a flag has not been awarded but to whom a salute is due.

In saluting foreign government representatives and officials the national flag or the naval ensign of the nation being saluted is used. The flags are hoisted to the fore truck and displayed together with own flags.

During the official visit aboard a Navy ship by the Ambassador Extraordinary and Plenipotentiary or the envoy of the USSR, the national ensign of the USSR is displayed. The ensign is hoisted to the main truck when an Ambassador is aboard the ship and to the fore truck when an envoy is aboard.

Whenever an Ambassador Extraordinary and Plenipotentiary or an envoy of the USSR as well as a charge d'affaires of the USSR are traveling aboard launches (boats) in an official capacity, the national ensign of the USSR is displayed from the foreward flagstaff. The flag is displayed within the territorial waters of that nation to which these individuals are accredited.

For consuls of the USSR the national ensign of the USSR is hoisted on launches (boats) only in those ports where these idividuals perform their duties.

The procedure for carrying out gun salutes and organizing of greetings, saluting of officials, personal visits, and other ceremonials during visits of foreign ports by Soviet warships are described in detail in the Handbook on Relationships with Foreign Ships and Powers.

CHAPTER 12

CERTAIN PROBLEMS IN SEAMANSHIP /337

Section 12.1. Ground Tackle and Mooring Gear

1. Ground Tackle

The ground tackle is a set of equipment and arrangements used in holding a ship in place when at anchor in a roadstead or harbor and, depth permitting, in the open sea. The ground tackle of a ship includes the anchors, anchor chains, hawse pipes (chocks), capstans, and anchor and chain stoppers.

In terms of their design, anchors are classified as bower and slewing anchors.

Bower anchors are designed to hold a ship in place. Ships are equipped with two bower anchors, while launches with a displacement of up to 35 tons have only one.

Slewing anchors are used along with bower anchors to maintain a ship in a specific position with respect to waves, wind, or current, and are subdivided into stern anchors (0.5 of the weight of a bower anchor) and kedge anchors (0.3 of the weight of a bower anchor). Slewing anchors are carried in the after part of the ship. Ships with a displacement greater than 800 tons are equipped with stern anchors and those with a displacement of up to 800 tons are equipped with kedge anchors. The weight of a kedge anchor for launches with a displacement of up to 35 tons is 1/5 the weight of the bower anchor.

The holding power of an anchor is the force required, per unit weight of the anchor, in breaking ground when the anchor shaft is in the horizontal position. The holding power depends on the anchor design and the nature of the bottom (Table 12.1).

The holding capacity of an anchor is the force that keeps a ship at anchor from moving under the effect of wind and current. The holding capacity of an anchor is the product of its holding power and weight. /338

The weight P of a bower anchor is, in kg:

$$P \approx 44S; \quad P = \frac{10\sqrt[3]{D^2}}{k}, \tag{12.1}$$

Table 12.1

Average holding power of anchors per unit weight

Nature of the bottom	Type of anchor			
	Hall's anchor	Matrosov anchor	Launch anchor	Admiralty anchor
Sandy	3 - 4	6 - 12	7 - 13	4 - 5
Gravelly	3 - 4	4 - 7	5 - 7	3 - 8
Muddy	2 - 3	11 - 17	5 - 24	2 - 4
Rocky	3 - 6	5 - 8	11 - 28	3 - 8
Clayey	-	5 - 8	-	-
Average value for all bottoms	3 - 4	6 - 11	7 - 18	3 - 6

where S is the area of the cross-section of the submerged part of the midship frame, m^2;

D is the total displacement of the ship, tons;

k is the coefficient of the anchor holding power (for Hall's anchors k = 1 and for the Matrosov anchors k = 2).

Hall's anchors, which are stockless anchors with rotating palms, are ordinarily used on the Soviet Navy ships and vessels as bower anchors. The Matrosov anchors, which have an increased holding capacity, and sometimes Hall's anchors, are used on launches.

The advantages of Hall's anchors are their lower holding power, in comparison with the Matrosov or Admiralty anchors of the same weight, and the difficulty involved in searching for a lost anchor, since they bury completely in the bottom. /339

Anchor chains are used for linking anchors to the hull of a ship and are classified according to the gauge, design, and the method used in making the links.

The gauge of anchor chains is determined by the diameter of the steel of which the links are made. On ships and auxiliary vessels chains with a gauge of 9 to 87 mm are used.

Anchor chains are made up of shots consisting of individual links with studs. (The latter, however, are not used on launches.) Each shot consists of an odd number of links and is 25 m in length. As a rule,

at the beginning and end of a shot there is one reinforced link and one end link. Individual shots are joined together by connecting links.

Depending on their position in the anchor chain, shots are designated as outboard (bending) shots, first shots, and intermediate shots. The outboard shot is secured directly to the anchor while the first shot is secured to the chain paying out gear. All other shots are called intermediate shots. In terms of design, there are welded and cast anchor chains.

Anchor chains are marked every 20 m (beginning with the anchor shackle), with markings made of soft annealed wire placed on the studs. The links with marks are painted as follows:

- at 20 m, one red link with a mark;
- at 40 m, two red links with marks;
- at 60 m, three red links with marks;
- at 80 m, four red links with marks;
- at 100 m, five red links with marks;
- at 120 m, one white link with a mark;
- at 140 m, two white links with marks;
- at 160 m, three white links with marks;
- at 180 m, four white links with marks;
- at 200 m, five white links with marks;
- at 220 m, one red link with a mark, etc.

On small ships it is permitted to mark chains every 10 meters.

The gauge and length of an anchor chain is determined for each ship /340
as a function of her displacement. Typical dimensions for chains are presented in Table 12.2.

Table 12.2

Typical dimensions of anchor chains

Class of ships	Starboard anchor chain		Port anchor chain	
	Gauge, mm	Length, m	Gauge, mm	Length, m
Cruisers	56 - 65	300	56 - 65	225
Destroyers	37 - 42	250	37 - 42	175
Frigates	29 - 37	225	29 - 37	125
Small ASW ships	15 - 17	100	15 - 17	50
Torpedo boats	15 - 17	50		

Safety measures in handling ground tackle are:

- members of the crew are not permitted between the capstan and hawse pipe during the heaving in or paying out of the anchor chain;

- disconnecting windlass wildcats when working with mooring lines is permitted only if the anchor chains are stoppered;

- before letting anchors go, make sure that the wildcats are properly secured to the windlass;

- when stowing anchor chains in chain-lockers do not let go the anchor until it is reported that all hands are in safe locations;

- when sending a man over the side to work with anchors and anchor chains secure him to a line; all tools delivered to the working area should be secured to lanyards.

2. Mooring Gear /34

Mooring gear is the set of equipment and machinery used in holding a ship in place when secured to a mole, pier, or alongside another ship.

Mooring gear includes mooring cables* (ropes) and hawse pipes, chocks, bollards, bitts, and machinery for hauling in and taking the slack out of the mooring lines as well as equipment for stowing them.

Wire rope is usually used for mooring lines while fiber and capron rope is used less frequently. The size of mooring lines depends on the ship displacement and type. The diameters of mooring lines for certain ships are as follows: cruisers, 56-60 mm; guided missile cruisers, 33-37 mm; destroyers and large submarines, 26-33 mm; frigates, seagoing minesweepers and medium-size submarines, 22-26 mm.

Safety precautions when working with mooring lines are:

- personnel working with wire-type mooring lines must wear gloves;

- lines should not have any protruding wires and broken strands;

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* Henceforth, instead of "cable" the term "line", traditional in sea practice, will be used.

- one should pass them from hand to hand when paying out mooring lines;

- turns of a line may be placed only on a stoppered capstan drum;

- the capstan should operate smoothly without jerks;

- it is prohibited to unreel a longer than required length of mooring line from the drum; any slack formed during the operation should be taken out immediately;

- the crew is not permitted near a very tight mooring line since serious injury may result if the line breaks;

- in paying out mooring lines it is prohibited to stand in the coils of a line spread out on the deck;

- in securing them to bitts, mooring lines must first be put on stoppers;

- in hauling in mooring lines, personnel at the back rope must be at least 1.5-2 meters from the warping drums.

Section 12.2. Cargo Handling Equipment /342

1. Whips

A whip is a running rigging tackle used for hoisting loads. It consists of a single fixed block and rope (pendant) passed over it (Fig. 12.1). Depending on the purpose for which they are used and on

Fig. 12.1. Whip

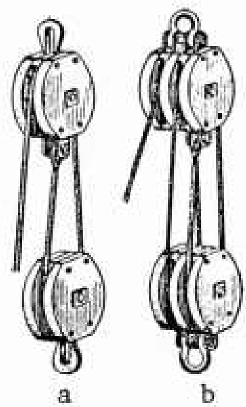

Fig. 12.2. Purchases
a - Double purchase
b - Bell purchase

the place of attachment of the fixed block, whips are called: yard tackle, sail tackle, boom tackle, and hoisting tackle.

Whips merely make it convenient to hoist cargo without producing any mechanical advantage. The force P applied to the fall of a whip is:

$$P = 1.1W \tag{12.2}$$

where W is the weight of the load being hoisted, kg.

2. Purchases

Purchases are hoisting arrangements consisting of two blocks with a rope (wire or fiber rope) pulled through them to facilitate the hoisting of loads (Fig. 12.2). Purchases are classified as simple and chain hoist type. Depending on the number of sheaves, they are also classified as:

- single purchases which are used in all types of guys (for example, for hauling home the boats);

- double purchases used for guying booms and for taking slack out of lines;

- triple purchases (luff purchases) used for hoisting small loads manually;

- bell purchases for hoisting ship's boats; and

- heavy purchases using 6 to 12 sheaves for hoisting heavy loads such as ship's launches, for example.

Purchases make it possible to obtain a mechanical advantage by reducing the rate of hoisting cargo. The theoretical mechanical advantage of all purchases, regardless of their direction, is equal to the number of branches of the fall passing from the movable to the fixed block, plus one, if the running part of the fall issues from the movable block. However, in practice, when working with purchases, it is necessary to /343
take into account the friction in the pins of the block sheaves and the absence of the absolute flexibility of the falls. In order to hoist a load under these conditions it is necessary to apply a force exceeding the theoretical force. The force P in kg applied to the fall of the purchase is

$$P = \frac{W + 0.1n \cdot W}{m}, \tag{12.3}$$

where W is the weight of the hoisted load, kg;

n is the number of sheaves which the fall traverses, including the sheaves of the fairlead blocks;

m is the theoretical mechanical advantage of the purchase.

A chain hoist (Fig. 12.3) is a complex block whose grooves carry cargo (chain) pendants with a cargo hook. The block sheave is rotated by a worm gear whose shaft carries a sheave with an endless chain in the grooves. Instead of worm gears, chain hoists may use a system of conical and cylindrical gears.

Chain hoists ensure high mechanical advantage (a factor of 16 or more). They hoist and lower loads smoothly, without jerks, and are ordinarily used in lifting and lowering engine blocks and heavy machinery parts. /344

The differential chain hoist (Fig. 12.4) is a type of chain hoist consisting of two sheaves. The lower sheave has a cargo hook and the upper sheave carries an endless chain connecting both sheaves. The differential chain hoist has a mechanical advantage of 16.

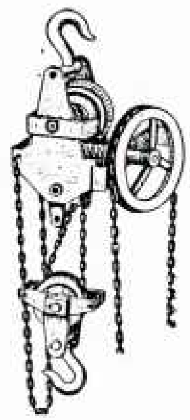

Fig. 12.3. Chain hoist

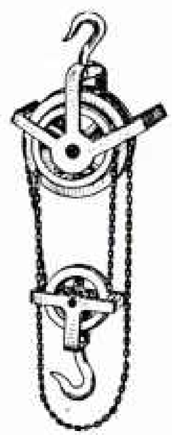

Fig. 12.4. Differential chain hoist

3. Boat Davits

Davits are used for hoisting and lowering boats. They are either swinging or hinged. For each boat two davits are installed, the design of which ensures movement of boats in the vertical and horizontal planes. Boat davits are equipped with boat tackle as well as with arrangements for securing the boats for sea.

The design load P acting on a boat davit is, in kg:

$$P = 0.5(W_1 + 1.1W_2 + W_3). \qquad (12.4)$$ /345

where W_1 is the weight of the boat with equipment and supplies, kg;

W_2 is the weight of the men (one man, 80 kg), kg;

W_3 is the davit own weight with the tackle, kg.

In ship practice it is sometimes necessary to calculate the force to be applied to the running falls of a purchase in hoisting boats by means of davits and to determine the number of men necessary to perform this task.

4. Safety Precautions When Working with Cargo Handling Equipment

The following safety precautions when working with cargo handling equipment have been developed in the practice of seamanship:

- begin cargo handling operations only when the weight of the cargo is known;

- make sure that in loading (unloading) cargo, the line has a safety factor of no less than 6 and no less than 14 when lifting people;

- do not overload hoisting gear; know the safe loads for all parts of the hoisting gear;

- hoist and lower the load smoothly without permitting it to swing;

- check and test with no load all hoisting equipment before using it; replace defective parts immediately upon detection of malfunctions in the hoisting equipment;

- make sure that there is nobody in the vicinity of the loading (unloading) who are not participating in this operation;

- do not stand beneath a load being lowered or hoisted;

- stay clear of moving lines and ropes;

- do not clear a foul rope without first stoppering the rope section located between the foul point and the load;

- when lowering a boat, the casting off boat falls depends on the movement of the ship. If the ship is not moving, the forward and after falls are cast off simultaneously; if the ship is moving ahead slowly the after fall is cast off first and if the ship is moving astern the forward fall should be cast off first.

Section 12.3. Ropes

1. Wire Ropes

Wire ropes are made from steel wires either galvanized to protect against corrosion or non-galvanized. In terms of their design wire ropes are either plain-laid (wire, yarn, rope) or cable-laid (wire, yarn, strand, rope). On ships use is primarily made of round-stranded plain-laid wire ropes. These ropes are approximately six times stronger than hemp ropes.

Wire ropes can be either rigid or flexible. A rigid wire rope, the strongest of the wire ropes, is used for standing rigging. It is made of steel wires more than 3 mm in diameter, without cores or with one core made of organic material. Flexible wire ropes are made of wires less than 3mm in diameter; each of their strands has a core made of plant fiber. These ropes are used in mooring lines, towing lines, trawl nets, running rigging, life lines and hoisting gear.

The approximate breaking strength R of wire ropes is, in kg*:

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* The exact value of parameters for all types of rope is given in the appropriate state standards (GOST 16874-71, GOST 3083-66, GOST 10293-67, GOST 1088-71, GOST 483-55, etc.).

- rigid rope: $$R = 40d^2 \qquad (12.5)$$

- flexible rope: $$R = 36d^2 \qquad (12.6)$$

where d is the wire rope diameter, mm.

The magnitude of the permissible tensile stress P (working strength) of a wire rope is, in kg:

$$P = R/n \qquad (12.7)$$

where R is the breaking strength of the rope, kg; /347

n is the minimum permissible margin of strength; for standing rigging it is 4; for running rigging and for hoisting loads--6; and for lifting and lowering people--14.

2. Fiber and Combination-type Ropes

Depending on the material used in making them, fiber ropes are:

- hemp rope, made of hemp (i.e., from the semifinished product obtained by treating the hemp plant);

- manila rope, made of fibers of the banana tree leaves;

- sisal rope, made of fibers of agave leaves;

- coir rope, made of fibers surrounding the hard coconut shell.

The most widely used rope in the Soviet Navy is hemp rope. According to their method of manufacture ropes are classified as follows: right-handed plain-laid ropes (twisted clockwise from left to right); left-handed plain laid ropes (twisted counterclockwise, from right to left); cable-laid ropes (consisting of right-handed plain-laid ropes twisted together counterclockwise); and braided ropes (slightly twisted strands, covered with flax braiding).

In terms of the method used in processing the yarn, hemp ropes can be untarred and tarred. The latter are somewhat heavier than the former but less susceptible to the effects of moisture and, consequently, more practical for use in water.

In terms of performance, depending on the grade and quality of the raw material, plain-laid ropes, both untarred and tarred, are classified as standard, high-strength, and special. The special rope which possesses high breaking strength, belongs to the highest strength group.

Depending on their circumference and on the method of manufacture, fiber ropes are referred to as:

- small stuff with a circumference between 8.8 and 37.7 mm;

- lines, with a circumference of up to 25 mm for plain-laid rope and up to 35 mm for cable-laid rope;

- rope, the circumference is 25-100 mm for plain-laid rope and 35-100 mm for cable-laid rope;

- hawsers, plain-laid rope with a circumference of 100-150 mm; /348

- mooring and towing hawsers, cable-laid rope with a circumference of 150-350 mm;

- cable, cable-laid rope with a circumference greater than 350 mm.

The approximate breaking strength R of fiber rope is, in kg:

- plain-laid hemp rope:

$$R = kC^2, \tag{12.8}$$

- cable-laid hemp rope:

$$R = 0.75kC^2 \tag{12.9}$$

where k is the strength factor (see Table 12.3) and

C is the rope circumference, mm.

The breaking strength of tarred rope is approximately 5% less than that for untarred rope of the same diameter. The magnitude of the permissible fiber rope tensile stress (working strength) is determined from Formula (12.7).

Table 12.3

Strength factor k for fiber rope

Standard rope		High-strength rope		Special rope	
Circumference of rope, mm	k	Circumference of rope, mm	k	Circumference of rope, mm	k
30	0.500	30	0.600	30	0.683
60	0.436	60	0.490	60	0.587
90	0.402	90	0.460	90	0.552
150	0.396	150	0.422	150	0.494
200	0.356	200	0.395	200	0.461
250	0.322	250	0.367	250	0.430
300	0.306	300	0.348	300	0.408
350	0.278	350	0.316	350	0.363

Combination-type ropes are ropes whose strands consist of steel wires covered with hemp strands. They are used for towing and mooring lines.

Rope from artificial (synthetic) fibers is made of capron, nylon, perlon, and other synthetic materials. In flexibility, resilience, water-resistance, and lightness they are superior to fiber ropes. Capron rope (the most widely used rope on Soviet Navy ships) is approximately 2.5 times stronger and more resilient than untarred hemp rope, and four times lighter in water. /349

Service life of rope:

- wire rope used in the running rigging, mooring lines and hoisting gear--2 to 4 gears. Rope for lifting loads and personnel are considered unsuitable for use if the number of broken wires over a length of the rope equal to eight diameters of the rope is more than 10% of their total number, or if an entire strand is broken;

- fiber rope: for cable-laid rope, 3 years; for hawsers, 2 years; and for all other rope, 1 year.

3. Marine Knots

A square knot (Fig. 12.5) is used for connecting two thin fiber ropes of the same diameter under slight tension (under great tension the knot tightens firmly); in tying the knot the standing and running parts of one rope should be on the same side of the loop of the other rope.

A reef knot (Fig. 12.6) is used for tying the knittles when tying reefs to the sails of boats. This knot is tied like the square knot; however, the running part of one of the knittles is entered into the knot as a loop. It is convenient because it can be quickly and easily released.

A sheet bend (Fig. 12.7) is used for tying sheets to the clews of sails; in this knot the running part of the sheet is passed through the eye of the cringle, brought around and passed under the standing part of the sheet.

A clove hitch (Fig. 12.8) is used for securing a rope to the middle of another rope, attaching a rope to masts and spars as well as for securing double sheets and tacks to sails (if metal thimbles are used).

A timber hitch (Fig. 12.9) is a tightening knot: a) an ordinary timber hitch is used to fasten a rope to a thick spar, pipe, or other

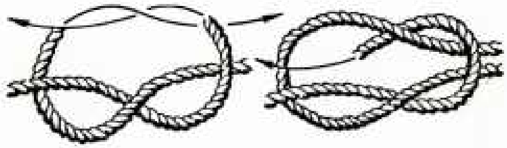

Fig. 12.5. Square knot

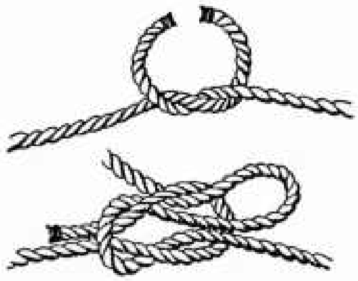

Fig. 12.6. Reef knot

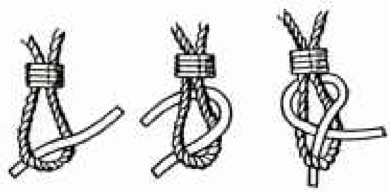

Fig. 12.7. Sheet bend

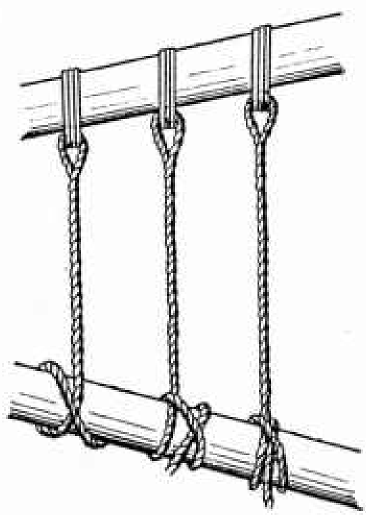

Fig. 12.8. Clove hitch

circular object; b) a timber and half hitch is used for towing circular objects or for hauling them.

Bends (Fig. 12.10): a) simple bend is used for securing mooring /352
lines with no eye splices on their ends and for joining two thick lines; b) round turn and two half hitches is used for the same purpose as the simple bend but, in contrast, it does not slide and under ordinary conditions, does not tighten; c) fisherman's bend is used for securing lines to boat anchors.

A carrick bend (Fig. 12.11) is used for joining two lines of different thickness.

A blackwall hitch (Fig. 12.12) is made with thick fiber rope; it
is used in temporary securing of towing lines to hooks; it is quickly /355
tied and easily released.

A stopper hitch (Fig. 12.13) is used for stoppering fiber mooring lines when transferring them from the capstan to bitts.

A bowline (Fig. 12.14) is used to secure a man working over the side or on the masts and spars in order to prevent him from falling. A correctly tied bowline does not tighten.

A boat knot (Fig. 12.15) is used for securing the running end of a line to a lifeboat; it is easily released by pulling on the running part.

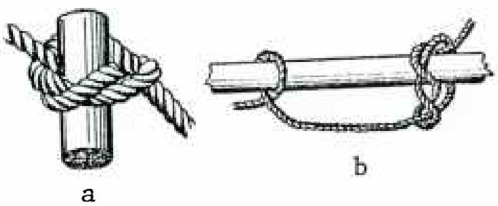

Fig. 12.9. Timber hitch
a - ordinary timber hitch
b - timber and half hitch

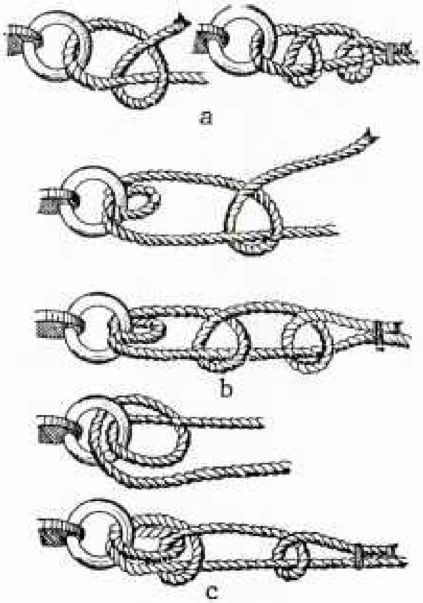

Fig. 12.10. Bends:
a - simple bend; b - round turn and two half hitches; c - fisherman's bend.

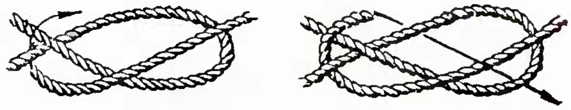

Fig. 12.11 Carrick bend

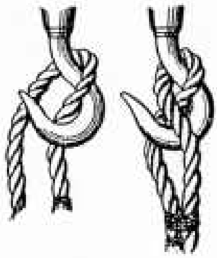

Fig. 12.12. Blackwall hitch

Fig. 12.13. Stopper hitch

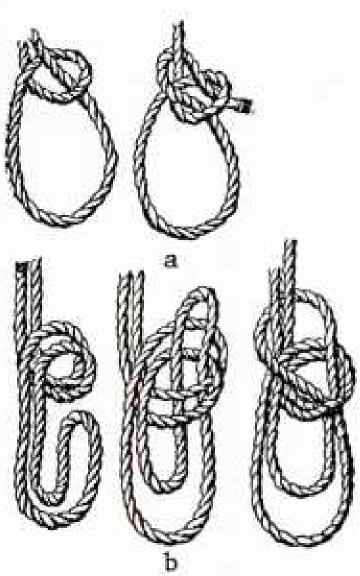

Fig. 12.14. Bowline
a - Ordinary;
b - bowline on the bight

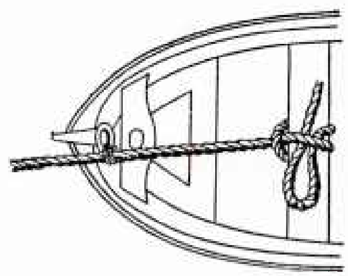

Fig. 12.15. Boat knot

Section 12.4. Ship's Floating Equipment and Lifesaving Gear

1. Ship's Floating Equipment

In terms of propulsion and design, ship's floating equipment is divided into boats and motor launches.

Boats include:

- longboats--large reliable boats with the number of oars ranging from 14 to 22 (they are no longer built);

- launches--boats of lighter construction than the longboats, with 10-16 oars;

- whaleboats--boats with single-banked oars (4-7) and sharply shaped bows and sterns;

- yawls--light boats with double-banked oars and transom sterns. In terms of the number of oars, yawls are classified as six-, four-, and two-oar yawls, and in terms of the material from which they are made yawls are classified as wooden boats (YaL-6, YaL-4, YaL-2), plywood boats (YaLSh-6, YaLSh-4, YaLSh-2), plastic boats (YaLP-6) and light alloy boats (YaLA-6);

- dinghy--short boats of light construction with two oars (for one oarsman);

Row and sail boats include the longboats, launches and yawls with six and four oars.

The seaworthiness and passenger capacity of the boats are given in Table 12.4.

The following motor launches belong to the inventory carried aboard ship:

- large motorboats--cruisers and other surface ships of the first rank are equipped with them; their hull is made of steel or glass-reinforced plastic; they are rated seaworthy in sea states of up to 5; and the passenger capacity is 11 persons; /356

- small commander's launches--ships up to the rank of destroyer and auxiliary ships are equipped with them; their hull is made of glass-reinforced plastic; they are rated seaworthy in sea states of up to 4; and the passenger capacity is 4 persons.

- large utility launches--cruisers and other surface ships of the first rank are equipped with them; the hull is made of steel or glass-

reinforced plastic; they are rated seaworthy in sea states of up to 5; and the passenger capacity is 50 persons;

- small utility launches--they are open boats; the hull is made of glass-reinforced plastic; they are rated seaworthy in sea states of up to 4; and the passenger capacity is 18 persons.

Launches (or boats) must never be overloaded. For each of them the load carrying capacity and passenger capacity should be determined in fresh weather and these data should be painted inside the deck houses on launches, and on the inner side of the transom on boats. Watch officers, Commanding Officers and coxswains must be familiar with these data. The load capacity of boats, when transporting compact and small cargoes, is determined by figuring that an 80 kg load replaces one passenger or one oarsman.

Table 12.4

Seaworthiness and passenger capacity of row-and-sail and row boats

Type of boat	Seaworthiness wind/sea, points	Passenger capacity with oars, persons	Passenger capacity with sail, persons
Longboats (20-oar and 12-oar)	5/6	5 (per oar)	Cuts in half
10-oar launch	5/4	5 (per thwart)	Cuts in half
6-oar whaleboat	5/4	13	8
6-oar yawl	4/3	13	8
4-oar yawl	3/2	9	6
2-oar yawl	2/-	3	-
Dinghy	2/-	2	-

2. Individual Lifesaving Gear /357

Individual lifesaving gear is designed to create additional buoyancy for people in the water as well as to insure the safety of the crew working on the main deck, over the side of the ship, or when using ship floating equipment; they are assigned to the individual members of the crew.

Types of individual lifesaving equipment:

- life jackets; they are made of closely woven linen fabric with eleven sections filled with sheet or crushed cork. Their weight is 2.8 kg; the buoyancy created is about 68 N (7 kg);

- life jackets and vests; they are made of closely woven cotton fabric which is quilted to form pockets containing airtight polyvinylchloride bags filled with cotton. Their weight ranges from 2 to 3.5 kg; the buoyancy is 147-294 N (15-30 kg);

- life vests--made of two layers of red rubberized fabric, forming two insulated air chambers. The vest can be inflated in the water or on board ship through two tubes. Its weight is about 2 kg and the buoyancy (inflated) is about 392 N (40 kg);

- inflatable life jackets--made of two layers of orange rubberized fabric, forming a buoyancy chamber. The jacket can be inflated from a gas-filling system or through an inflating tube (in emergency). It has a special strap for lifting a man out of the water, a signalling light, and a whistle for sound signalling. The weight is about 1.3 kg and the buoyancy is about 176 N (18 kg).

The individual lifesaving equipment also includes life rings, spars, buoys, and cork mats. Life rings are made of canvas and filled with cork. The weight of a ring is about 6 kg and the lift force about 136 N (14 kg). A life ring can support two men in the water, with each man holding onto the lifeline beckets.

3. Group Lifesaving Equipment /358

The use of group lifesaving equipment is determined by a special bill. Group lifesaving equipment is divided into three basic groups: rescue launches, rescue boats, and life rafts.

The majority of surface ships carry life rafts, both rigid (open or closed type) and inflatable. Specifications of life rafts of various designs are presented in Tables 12.5 - 12.7.

Table 12.5

Specifications of steel life rafts (SPS)

Parameters	SPS-12	SPS-18	SPS-24
Length, m	1.73	2.25	3.55
Width, m	1.53	1.55	1.85
Weight of raft with equipment, kg	180	270	420
No. of rescued men on raft	2	4	8
No. of rescued men holding onto the lifeline	10	14	16

Table 12.6

Specifications of SPA and SPP life rafts

Parameters	SPA-6	SPA-12	SPP-6	SPP-12	SPP-18
Length, m	2.56	3.26	2.46	3.04	3.98
Width, m	1.82	2.59	1.64	2.19	2.29
Permissible dropping height, m	18.3	18.3	18.3	18.3	18.3
Area of deck, m^2	2.47	4.46	2.64	4.60	7.00
Passenger capacity, no of men	6	12	6	12	18
Weight of raft with equipment and emergency supplies (water, food), kg	180	280	170	240	320

Table 12.7 /359

Specifications of inflatable life rafts

Parameters	PSN-6M	PSN-10M
Length, m	3.1	3.7
Width, m	1.8	2.4
Height, m	1.2	1.4
Number and capacity of gas cylinders, units/liter	1/4	1/6
Time required to prepare raft from the moment it is dropped into the water, sec	20	30
Load capacity:		
Normal, no. of men	6	10
Overload, no. of men	12	20

CHAPTER 13

BRIEF INFORMATION ON THE INTERNATIONAL MARITIME LAW

Section 13.1. The Legal Status of Inland Sea Waters of Coastal Nations /360

According to the 1958 Convention on the Territorial Sea and Contiguous Zone*, "waters located in the direction of the shore from the starting line of the territorial sea** constitute a part of the inland waters of a state."

Inland sea waters are a part of the territory of a coastal state and are under its exclusive jurisdiction*** and sovereignty****.

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* The Convention was ratified by the USSR on 20 October 1960 and became effective on 10 September 1964. For the text see <u>Vedemosti Verkhovnogo Soveta SSSR</u> (Records of the Supreme Soviet of the USSR), 1964, No. 43, p. 472. Henceforth any partial changes, additions, or replacement of the Sea Conventions of 1958 should be kept in mind pursuant to the 1975 UN Conference on Maritime Law and its subsequent signing and ratification by member nations.

** According to the Soviet terminology the words "territorial sea" are understood here and henceforward to mean "territorial waters."

*** Jurisdiction is the honoring of the laws and regulations of the appropriate state and the right on the part of that state to take court action or to resolve special problems which fall within the sphere of competence of its offices.

****Sovereignty is the complete independence of a state in conducting its external and internal affairs.

The legal regime of inland sea waters is regulated by national laws of the coastal states, issued on the basis of the provisions of the above Convention.

Inland sea waters include (Fig. 13.1):

a) the waters of interior roadsteads, harbors, seaports, and naval bases, measured from the shoreline (or from the low-water line) to a line connecting the outermost parts of permanent port (hydraulic) struc-

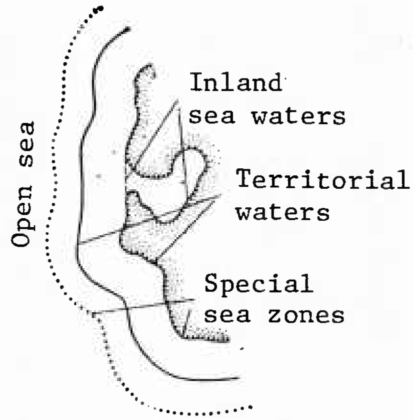

Fig. 13.1. Territorial waters, inland sea waters, and special sea zones

tures that project into the sea and comprise a port (base) system. Outer roadsteads having an anchorage site for vessels and boundaries marked on nautical charts are, as a rule, included in the territorial waters (Article 9 of the Convention) and are not inland waters;

b) the waters of gulfs, bays, estuaries, and inlets cutting rather deeply into the shore of a coastal state. Moreover, only that part of /361 a gulf (in the direction of the shore) which begins at the point where the starting line (entrance width into the gulf) does not exceed 24 miles, is included in the inland sea waters of a coastal state;

c) the waters of historic gulfs, regardless of their entrance width;

d) the waters in a region of skerries. In drawing baselines no appreciable deviation from the general direction of the shore can be made. The length of the starting lines, as in determining the waters in the gulfs, must not exceed 24 miles. In some cases, however, states may take into account the special economic and other interests of a given region and make the length of these lines different;

e) inland seas, surrounded by the shores of one state, and their access zones connecting these seas with open or closed seas.

Each coastal nation establishes in its own inland waters: /362

- sailing regulations (navigational rules);

- piloting and towing rules and regulations;

- a system for specifying restricted and dangerous navigational regions;

- customs and sanitary inspection regulations;

- anchorage sites;

- regulations on the use of ship radio and radar equipment;

- regulations on aircraft flights;

- fishing, sea exploration and other regulations relating to the economic interests and security of the coastal nation.

Under certain conditions warships may enter inland sea waters. In terms of purpose and mission, there are the following types of visits*

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* Guide to Relations With Foreign Warships and Authorities, 1972, pp. 157-200.

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by warships to foreign inland sea waters and ports:

- official visits;

- unofficial visits;

- business calls;

- emergency calls.

The general rules for warships entering foreign waters and ports amount basically to the following:

Visits of foreign inland sea waters and ports by warships (except emergency calls) are usually made after receiving authorization through diplomatic channels and during the time period established by the coastal nation.

As a rule, warships have a right to enter open foreign ports and sea waters, i.e., open for international trade and for calls by foreign merchant vessels. A list of such waters and ports is usually published by coastal states.

Warships do not have the right to enter closed regions of inland

sea waters, naval bases, or ports serving coastal ships without special authorization of the coastal state.

Upon receiving authorization for a call Commanding Officers of warships should observe the national legal rules for entering foreign territorial waters and ports as well as the regulations and customs observed in the country of visit. /363

The coastal state in the port of which the arrival of warships is anticipated should be informed by radio, following the receipt of authorization, no less than 4 hours in advance, of the exact time of their arrival and time of their meeting with the pilot (local time). Upon entering the harbor (port) the warships must proceed along the fairway open for the passage of all ships and observe the established navigational and port regulations.

Submarines may enter foreign waters and ports and remain in them only in the surface condition while flying their naval ensign.

In the region of a port or at its approach where piloting is mandatory pilots should be used. The Commanding officer of a ship may also use a pilot in other instances when he is not sure that the sailing directions and charts of certain regions of foreign sea waters and harbors can insure navigational safety.

In compliance with the legislation of individual states, the entry of warships with nuclear power plants into their waters and ports takes place upon receipt of special diplomatic permission from the coastal state.

Without authorization from the foreign authorities the use of helicopters, launches, ship's launches and boats for the purpose of communication with the shore is prohibited as well as the use of ship radio and radar equipment without any special need.

In ports it is forbidden to conduct combat training, gunfire, or blasting; to set up smoke screens and mines; to take depth soundings; to release atmospheric or sounding balloons; to take photographs or make sketches (diagrams) of port structures and military or government installations; to engage in fishing; or to discharge oil and other /364
waste products into places that have not been set aside for these purposes. The diving by submarines and submarine navigating in the submerged condition is prohibited in foreign inland sea waters and ports.

With permission from the authorities of a foreign coastal state, through an arrangement with its diplomatic representatives, aircraft may take off from a ship, urgent and other messages may be transmitted by radio, divers may be lowered for carrying out inspection or minor

repair of the underwater part of the hull of own ship, and armed or unarmed details for participation in parades and other ceremonies may be taken to shore.

If a warship or members of her crew violate the laws and regulations of the coastal state, then its appropriate authorities have the right to bring this to the attention of the Commanding Officer of the ship and, in special cases, to demand that the ship leave the roadstead or the waters of the state.

The legal status of the warship crew members who are on the shore of a foreign state is determined by the following regulations:

- crew members violating the law of the host country while performing official duty enjoy legal immunity but can be held accountable under the laws of their own state;

- crew members who are not performing official duties or tasks and who violate the law while on leave, do not enjoy legal immunity. They can be held accountable under the laws of the host country. In such a case, local judicial authorities should present a copy of the indictment to the Commanding Officer of the ship and to his diplomatic representative in the host country. The question of time and site for serving a sentence is subsequently resolved through competent diplomatic and judicial authorities of the parties involved;

- crew members who are not subject to legal accountability for the violation of the law are turned over to the Commanding Officer of the ship for prosecution under the laws of his country.

Officers possess legal immunity from foreign jurisdiction and can /365
be held accountable only under the laws of their own country.

The Commanding Officer of a warship is granted special rights. The Commanding Officer of the ship is the official representative of his country in all relations with foreign authorities and ships and therefore he performs official duties and possesses an exceptional (complete) legal immunity from foreign jurisdiction at all times. The Commanding Officer of the ship is accountable for his actions under the laws of his country. If the rights of the warship (or members of the crew) are violated or the illegal restrictions imposed by local foreign authorities, the Commanding Officer of the ship has the right to file a written or oral protest and, for the purpose of settling the dispute through diplomatic channels, to establish immediate contact with a diplomatic (or consular) representative of his state.

The procedure for the departure of a warship from a foreign port is: the local authorities are informed of the exact time of departure

of the ship from port: also, through the communications officer, letters of thanks are transmitted to the senior maritime official, to the Commander of the port and to other officials visited. Following departure of the ship from the waters of the coastal state telegrams of thanks, written in a brief informal manner, are sent by radio.

Special international rules regulating the execution of salutes do not exist. However, there are generally recognized international rules which each maritime state establishes through legislation or by a departmental (administrative) act.*

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* Guide to Relations with Foreign Warships and Authorities, 1972, pp. 140-156.

Section 13.2. The Legal Status of the Territorial Waters of Coastal Nations

The national sea boundary of coastal states constitutes the outer limits of the territorial waters. The 1958 Geneva Convention on the /366 Territorial Sea and Contiguous Zone provides that "the sovereignty of a coastal state extends beyond the limits of its land territory and inland waters to the so-called "belt of sea adjacent to its coast and known as the territorial sea." Sovereignty also applies to the air space over the territorial sea as well as to the surface and interior of the sea bottom. All this comprises a part of the territory of a coastal state. The legal regime of territorial waters is regulated by the above Convention and by national legislation of the coastal states.

A single norm for the width of the territorial waters is not defined by the Convention. As a result, the width of the territorial waters is, as a rule, established by coastal states within 12 miles (see Section 14.1). Methods of determining the territorial waters are established by national maritime legislation of coastal states in accordance with the 1958 Convention.

In the USSR the width of the territorial waters has been established at 12 miles. It is reckoned from the low-water line, both on the main- /367 land and around islands, or from the line of the outer boundary of the inland sea waters of the USSR; and in those regions where the shoreline is extremely jagged, or where along the shore and in its immediate vicinity there is a chain of islands, it is reckoned from the straight starting lines connecting the appropriate points. This line is the inner boundary of the territorial waters (Fig. 13.2).

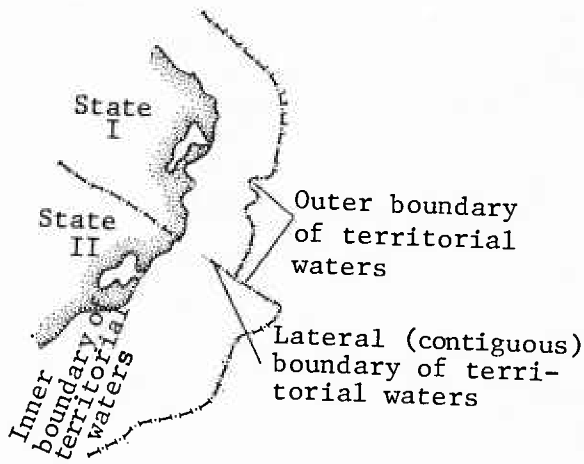

Fig. 13.2. Boundaries of the territorial waters

The low-water line of natural elevations of land which dry with the reflux of water can be used as the starting line for measuring the territorial waters, provided these elevations are located at a distance (from the mainland or islands) that does not exceed the width of the territorial waters. Elevations of land which dry with the reflux of water cannot have their own territorial sea if with the reflux of water they are located from the mainland or islands at a distance that exceeds the width of the territorial sea.

Starting lines can be drawn to elevations of land that dry with the reflux of water or away from them only if lighthouses or other similar structures that are always above the level of the sea have been erected on them. The coastal states must clearly mark the starting lines (base lines) on nautical charts that are to be published.

The outer boundary of the territorial waters is the line parallel to the inner boundary of the territorial waters located at a distance equal to the width of the territorial waters of the coastal state. The outer boundary of the territorial waters is the national sea boundary of the coastal state.

The lateral boundary of the territorial waters is the line separating the territorial waters of two adjacent (contiguous) states. This line is an extension of the national land boundary of two neighboring states and is fixed, as a rule, by agreement between them; it is marked on large-scale nautical charts.

If the shores of two states are located opposite one another, neither one of these contiguous states has the right, if there is no

agreement between them, to extend their territorial waters beyond the center line drawn in such a way that each of its points is equidistant from the nearest point of the starting line from which the width of the territorial waters of these two states is measured. However, this rule does not apply if, by virtue of historical legal circumstances or other special circumstances, it is necessary to separate the territorial waters of two states in some other way. The boundary between the territorial waters of two such contiguous states is marked on large-scale nautical charts, officially approved by coastal states.

In the majority of cases warships may enter foreign territorial waters and stay there only after obtaining the diplomatic permission of that state to which the waters belong. The right to enter foreign territorial waters is enjoyed by those warships which proceed to the inland sea waters and ports of the respective coastal state in accordance with the diplomatic agreement.

In addition, the right to enter foreign territorial waters, to stop there and drop anchor (without prior diplomatic authorization or special notification of the coastal state) have those warships whose entrance was forced because of the special situation such as storm, breakdown of machinery, and other important factors which temporarily prevent ships from continuing their cruise. In entering foreign territorial waters submarines should be on the surface and they should fly their flag.

An authorization procedure for entering territorial waters by foreign warships has been established by such nations as the USSR, the Polish People's Republic, the German Democratic Republic, the People's Republic of Bulgaria, the Socialist Republic of Romania, the USA, Turkey, Indonesia, Pakistan and many others.

Some coastal states, through legislation or by special agreement, permit the entry of foreign warships into their territorial waters without any previously obtained diplomatic authorization or special notification; however, they impose certain conditions regarding the /369 number of ships entering at one time, restrictions on anchoring, etc. Such nations are Sweden, Norway and Denmark.

Warships and non-military vessels entering territorial waters illegally are considered to be violators of the national boundaries with all the resulting consequences. The violators are also those warships and non-military vessels which, upon entering the territorial waters, deliberately transmit false distress signals. Both naval and Coast Guard authorities of the coastal state have the right, in this case, to order the foreign warship or non-military vessel, which has violated the national boundary, to leave the territorial waters immediately and, if the said order is not carried out, to take all necessary measures, including the use of force.

International maritime agreements contain rules for the so-called "innocent passage" by foreign non-military vessels through the territorial waters of coastal states. In accordance with Article 14, Paragraph 2, of the 1958 Convention on the Territorial Sea and the Contiguous Zone, the "innocent passage" is understood to mean sailing through territorial waters by foreign vessels for the purpose of crossing these waters without entering inland sea waters, or for the purpose of entering them or sailing from them into the open sea. However, the implementation of this rule is limited since any coastal state has the right to temporarily suspend or prohibit the passage by foreign vessels through its territorial waters if such measures are of vital importance to its security.

The passage by foreign warships and non-military vessels, which violate the laws of a coastal state and its regulations banning fishing in its territorial waters, is not considered "innocent"; it causes economic loss to fishing or interferes with it.

The Soviet maritime law recognizes the right of "innocent passage" only for non-military vessels of foreign nations and only in accordance with special agreements concluded with them, indicating the regions where such passage through the territorial waters of the USSR is permissible. The 1960 Statute on the Protection of the National Boundary /370
of the USSR recognizes passage as "innocent" if foreign vessels sail the usual course or a course recommended by proper authorities, with the observances of the established mode of navigation and only in those places where there are no areas closed to navigation, as published in Notices to Mariners.

The passage by foreign non-military vessels through the territorial waters of the USSR may, if necessary, include stopping and anchoring necessitated by the insurmountable weather elements or natural calamity.

Section 13.3. The Legal Status of the Continental Shelf

The legal status of the continental shelf established by the 1958 Convention on the Continental Shelf signed in Geneva by maritime countries (including the Soviet Union),* as well as by national maritime laws of coastal states.

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* The text of the Convention is published in Vedomosti Verkhovnogo Soveta (Records of the Supreme Soviet), 1964, No. 28, (1219).

The legal term "continental shelf" is understood to mean the surface and the interior of the sea bottom of underwater regions, contiguous to the shore of the mainland and the islands located outside the zone of the territorial waters, to a depth of 200 meters or to the point where the depth of the waters permits exploration of natural resources in these areas by the coastal states (Fig. 13.3).

The rights of coastal states to explore their own continental shelf does not affect the legal status of the waters covering the continental shelf or of the air space above these waters. This means that all states in the continental shelf region have equal rights to enjoy freedom of navigation by civilian and naval ships, fishing, and over-flights by aircraft, provided they obey the rules specified by the Convention and the national legislation of the appropriate coastal state.

Commanding Officers of warships should take into account that obstacles resulting from the construction of special installations neces- /371
sary for the exploration of natural resources of the World Ocean may pose a threat to free navigation in the continental shelf region. The Convention obliges the coastal states to establish safety zones around such installations with a radius of 500 meters from each extreme point of the installation, as well as to take necessary measures in safeguarding these zones.

Appropriate official notices concerning the construction of installations and the establishment of safety zones should be given along with an indication of the location of any permanent or temporary warning facilities. Structures that are not being used should be removed. The installations themselves and their safety zones should not be located in areas of heavy sea traffic.

The installations and safety zones around them are under the jurisdiction of the coastal states but do not have their own territorial waters.

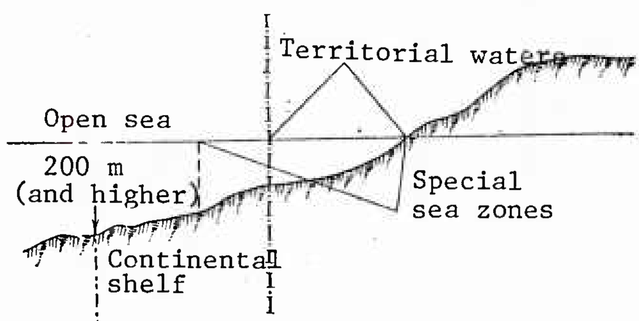

Fig. 13.3. The continental shelf

Section 13.4. The Legal Status of the High Seas

The legal status of the high seas (international waters) was established by the 1958 Convention on the High Seas* signed in Geneva by /372

* The Text of the Convention is published in the Vedomosti verkhovnogo Soveta (Records of the Supreme Soviet of the USSR), 1962, No. 46.

the maritime countries (including the Soviet Union).

The high seas include all the waters of the sea and their access zones located beyond the limits of the territorial waters of coastal states.

All states and their instruments (ships, vessels, aircraft, etc.) on the high seas must take into account the mutual interest in enjoying the right of freedom of the high seas which consists of the freedom of navigation (naval, merchant marine, etc.), fishing, the laying of cables and pipes, flights over the high seas, and freedom of scientific investigations. The freedom of the high seas is a universally recognized principle of modern international law. States and their authorities do not have the right to resort to measures which could preclude the operation of the principle of the freedom of the high seas.

The legal status of warships and military aircraft on the high seas. Warships on the high seas are subject to the laws of their own state. At the same time they should, however, comply with the international norms and principles fixed by conventions and sea customs and applied to the waters of the open seas. Warships and military aircraft (planes, helicopters, etc.) on the high seas enjoy the right of immunity, i.e., they are not liable and not subject to the laws of foreign states.

In the legal sense the warships and aircraft of different states are equal. However, when meeting on the high seas they must observe the established international rules on navigational safety, naval ceremonials, rescue operations and the rendering of assistance at sea.

In accordance with the provisions of the Convention on the High Seas warships have the right to take action directed at the elimination of piracy* and slave trade as well as to stop non-military vessels suspected of breaking (damaging) underwater cables. Warships have the right to stop and inspect non-military vessels only in very special cases if they have sufficient ground for suspecting that the vessel is /373

either a pirate vessel, engaged in slave trade, or is guilty of breaking (damaging) an underwater cable.**

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* Pirates, regardless of their citizenship, are criminally responsible in accordance with the laws of the state whose ship seized them. Pirate ships are deprived of the right of defense by the state whose flag they fly.

** In the event a vessel suspected of damaging a cable is stopped, only those documents are examined which may make it possible to establish the vessel's course, the region of navigation, anchorage site, etc. A statement concerning the damaging (breaking) of a cable is drawn up.

The text of the 1884 Convention on the Protection of Underwater Telegraph Cables is published in the <u>Collection of International Agreements and Legislative Acts of the USSR on Navigational Questions</u>. Moscow, GUNiO Ministry of Defense of the USSR, 1971.

A warship on the high seas also has the right to pursue and hold a foreign non-military vessel that has violated the laws of the coastal state to which the pursuing ship belongs. The pursuit is considered legal if:

- the pursuit is conducted by a warship (or military aircraft) after the transmission of a visual or sound signal from a distance permitting it to be seen or heard;

- the intention is to detain and bring the vessel that has violated the laws of a coastal state into port;

- the pursuit begins in inland waters, territorial waters, or in contiguous sea zones;

- the pursuit is carried out continuously up until the violating vessel enters its own or foreign territorial waters, after which the pursuit must cease.

Pursuit should be distinguished from surveillance which aims only at solving specific problems associated with the daily activity of warships in international waters (on the high seas). Surveillance can and should be conducted in accordance with the generally recognized principles and norms of the international maritime law and with the provisions in the agreement between the Government of the Union of

Soviet Socialist Republics and the Government of the United States of America on the prevention of incidents on the high seas and in the air space above them, signed in Moscow, 25 May 1972.

Ships and planes operating in the vicinity of one another should remain at a distance sufficient to avoid the risk of collision. They should not take action to simulate attack by training guns, launchers, torpedo tubes or other types of weapons in the direction of an approach- /374
ing ship or plane, they should not eject objects in this direction, use searchlights, or any other powerful illumination equipment. The agreement provides for a commitment of the parties to observe strictly all the rules dealing with the safety of navigation and aircraft flights.

Rendering assistance at sea. In carrying out rescue operations and rendering assistance at sea the following basic rules should be observed by the Commanding Officer of a warship and the Officer of the Watch:

- in case of a collision effective measures are taken with the aid of visual and sound signals to stop the ship involved in the collision should it attempt to flee (evade responsibility);

- after a collision assistance is rendered to the distressed ship, her crew, passengers, and cargo. A bilateral statement is rendered to the distressed ship, her crew, passengers, and cargo. A bilateral statement is drawn about the collision or whatever the accident is (at the site of the accident, if possible) along with a statement of the results of the assistance rendered; all this information is recorded in the watch journal (see Annex No. 3 and No. 4 of the Guide to Relations with Foreign Warships and Authorities, 1972);

- in rendering assistance to a damaged ship measures should be taken to rescue items of material value at reasonable risk and, if necessary, to sacrifice that which is less valuable, i.e., measures should be taken to avoid more significant losses (loss of the ship, vessel, or valuable cargo) by jettisoning some cargo, equipment or ship supplies for the purpose of freeing the ship (vessel) that has gone aground or for rescuing the ship from any other emergency situation created by the collision or stormy weather;

- upon receiving a distress signal, when in or near the area where there is an emergency, notify your superiors about the emergency and, after receiving the appropriate instructions, communicate by radio or some other means with the ship in distress and proceed at flank speed to render assistance.* Upon arrival at the site of the emergency (accident) it is necessary to survey the situation and, guided by the principles of rendering assistance at sea, proceed to carry out rescue

* To render assistance to ships and aircraft, signals are transmitted at a frequency of 500 kHz (600 m). Sometimes a frequency of 489 kHz (613.5 m) or 2182 kHz (137.5 m) is used.

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operations as specified in Annexes No. 5 and 6 of the Guide to Relations with Foreign Warships and Authorities, 1972. /375

The national legislation of many countries (including the USSR) affirms the right of warships to just compensation for any act of rendering assistance or any successful rescue. Though fees are levied for ordinary towing, compensation is not paid for it and a rescue contract is not drawn up. Ordinary towing is understood to mean the towing of a vessel (ship) which is not in any real danger of loss or damage.

In no instance is compensation paid for the rescue of people since this action is an age-old sea custom and the gratuitous duty of every seaman.

The general principles for all nations on rendering assistance at sea are contained in the 1958 International Convention on the High Seas which points out that "every state imposes upon the Captain of any vessel flying his flag the following duties, provided that the Captain can do so without subjecting his vessel, crew, or passengers to any serious danger:

a) to render assistance to any individual detected in the water whose life is in danger;

b) to proceed at the highest possible speed to extend the aid to those in distress, if he has received a message that they are in need of assistance and provided that he can reasonably be expected to do this;

c) after a collision to render assistance to the other ship, her crew, and passengers and, if possible, to communicate to the other ship the name of his own vessel, port of registry and the nearest port of call."

The Soviet Union, taking into account the importance of rendering assistance at sea and following the basic principles of the Convention on the High Seas and its norms, signed special agreements on cooperation in the rescue of human lives and on rendering assistance to vessels and aircraft on the high seas with Denmark, Sweden, Finland, Poland, the German Democratic Republic, Romania, Bulgaria, Norway,

Japan, the People's Republic of China, and the People's Democratic Republic of Korea.

A certificate on the rescue or the rendering of assistance on the high seas is drawn up on a form of the Maritime Arbitration Commission /376 (see Annex No. 3 of the Guide to Relations with Foreign Warships and Authorities, 1972).

Section 13.5. International Straits

In the majority of straits there is freedom of international navigation and those straits which are not part of territorial waters, offer freedom of overflights by aircraft as well.

However, there is no single international convention regulating the navigation through straits. At the same time Article 16, Paragraph 4, of the 1958 Geneva Convention on the Territorial Sea and Contiguous Zone states that "it is forbidden to halt the innocent passage of foreign vessels through straits which connect one part of the open sea with another or with the territorial sea of a foreign state and which are used for international navigation."

Despite this, certain coastal states interpret the concept of "innocent passage" in the one-sided manner and attempt to establish control over navigation through straits. Only with respect to the Black Sea and Baltic Sea straits have international conventions, in effect at the present time, been concluded.

Black Sea Straits (Bosporus, Sea of Marmara, and the Dardanelles). The 1936 Convention on the Black Sea Straits in Montreux (Switzerland) established the procedure for using the straits by non-military vessels and warships and defined the conditions to be used by warships of the Black Sea nations and nations which are not littorals of the Black Sea.

In time of peace warships of the Black Sea nations are permitted to sail through the straits under the following conditions:

- only the Black Sea nations are permitted to send battleships of any size through the straits.* These ships pass through one at a time,

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* Ships with a displacement of more than 10,000 tons or ships with a displacement of no more than 8000 tons and carrying guns with a caliber of over 203 mm are considered to be battleships.

escorted by no more than two destroyers; /377

- only the Black Sea nations have the right to pass submarines through the straits (in daytime, one at a time, and in the surface condition).*

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* Article 12 of the Convention states that only those submarines have the right of passage through the straits "for the purpose of returning to their base" which were constructed or purchased outside of the Black Sea area, provided Turkey "was informed beforehand about their construction and purchase." In addition, submarines of the Black Sea nations may pass through the straits "for repair at shipyards located outside of this sea, provided Turkey is notified of the exact date of sailing."

Notices concerning the sailing of ships of the Black Sea nations through the straits must be sent to Turkey via diplomatic channels 8 days in advance. At the same time it is recommended that non-littoral nations send such notices 15 days in advance.

In time of peace warships of non-littoral nations may enter Black Sea ports on friendship visits. However non-littoral nations are not permitted to send to the Black Sea and into the zone of the straits warships with displacements greater than 10,000 tons or submarines; the total tonnage of surface ships which may be sent to the Black Sea and remain there at any one time may not exceed 45,000 tons. The limit for one non-littoral nation has been established at 2/3 the maximum tonnage (45,000 tons).

Warships of non-littoral nations, regardless of the purpose of their visit to the Black Sea, may not remain there more than 21 days.

Light navy surface ships and auxiliary ships belonging to Black Sea nations and non-littoral nations enjoy freedom of passage through the straits in time of peace (in daytime), upon advance notice and without any fees or payments. Auxiliary navy ships equipped exclusively for transporting fuel (oil, etc.) enjoy free passage through the straits without sending any notices if they carry no more than two 105 mm guns and two 75 mm antiaircraft guns.

Piloting through the straits is not mandatory but a pilot may be requested if needed.

All ships approaching the Bosporus or Dardanelles must, at a dis- /378

tance of 50 miles, report by radio to the Turkish signal station the composition of the detachment, the name and call signals of the ships (ship) and the expected time of entering the strait. This message is repeated visually when the ship is in the immediate vicinity of the straits (Bosporus, Dardanelles).*

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* The visual call signs of both stations are: Kh-1 (N-1); radio call signals of the Bosporus (Anadolu) station: TBC-1; calling frequency, 500 kHz and the working frequency is set by agreement; radio calling signals of the Dardanelles station (Seddul'bakhir): TBG-1; call frequency, 500 kHz and the working frequency is set by agreement.

In the Bosporus and in the narrow channels of the Dardanelles (from Cape Nara to the lighted Kepez Buoy) ships and vessels must maintain a speed of under 10 knots. The speed must be reduced to a minimum between the Bay of Bukdere and the Bay of Umurjeri and between Cape Akhyrkapy and Haidar Pasha Harbor in the Bospurus, and in the Dardanelles, between the city of Galibolu (Gallipoli) and Cape Chardak and between Cape Mekhmetchik and Cape Kumkale.

Ships and vessels sailing south through the Bospurus must keep closer to the Asiatic coast when in the regions between the lighted Kirech buoy and the buoy of the Umujeri banks and between the Ortakey Mosque and the lighted buoy of Kyzkulesi. However, those proceeding north must stay closer to the European coasts., i.e., they must sail left of the center of the strait. The constant southerly current of up to 2 knots (up to 4 knots in fresh weather) in the Bospurus strait should be taken into account.

Saluting batteries are positioned at both entrances to the straits as well as at Haidar Pasha (destroyers and auxiliary ships of the Navy do not have to exchange salutes with this battery); by agreement the ships may, however, exchange salutes only with the battery at Haidar Pasha.

If in time of war Turkey is not a belligerent party, warships of littoral and non-littoral nations of the Black Sea have the right of free passage through the straits under the conditions indicated above. This right does not apply to warships of belligerent nations which may attempt to sail to the Black Sea with hostile intent. Under no circumstances do warships of belligerent nations sailing in the Black Sea straits have the right to make inspections or conduct any type of seizure or hostile action.

If in time of war Turkey is a belligerent party issuance of the permission for passage by warships depends solely on the Turkish government. /379

The Baltic Sea Straits (Great and Little Belts, and the Sound). The legal rules governing passage through the straits were established by the 1857 Treaty of Copenhagen and by national legislative acts of Denmark and Sweden.

The passage by warships through the Danish straits (the Sound and Great Belt) is free if the number of surface ships or submarines does not exceed three units and the time for passing is no greater than two days. Submarines must sail in the surface condition with flags hoisted.

The passage of ships through the Little Belt and the Copenhagen roadstead (through Hollenderdub and Drogen) requires, under all circumstances, that notices be sent to Denmark 8 days in advance.

If a detachment of ships of one nation consists of more than three units or if it will take more than 4 days to sail through, then Danish authorities must be notified in advance via diplomatic channels.

The passage of ships through the Swedish section of the sound is free but an arbitrary stopping or anchoring is not permitted.

Non-military vessels have the right of free and unlimited passage through the straits, without paying tolls. The rules specified for warships apply to training vessels and yachts sailing under the merchant flag as well. The above restrictions do not apply to ships in distress. According to the agreement between the USSR and Denmark of 9 October 1965 on rescue and salvage operations in Soviet and Danish waters, the free access of vessels of both nations to the territorial waters of the USSR and Denmark is permitted for the purpose of rendering assistance and for rescuing ships and cargoes.

Military aircraft have the right of free flight over the straits of the Great Belt and the Sound but they must keep to the center of the straits (if possible, farther away from the Danish coast). Before entering the air space over these straits, aircraft must establish radio communication with the central control service for air traffic in Copenhagen (OUSN).

The Collection of Regional Agreements and Legislative Acts of Foreign Nations on Questions of Navigation, Vol. 1, 1968, published by the Main Administration, Department of Defense of the USSR, contains the following: certain provisions on the organization of visits to Denmark by foreign warships; the decree on the permission for foreign warships and aircraft to visit the Danish territory in time of /380

peace; certain regulations dealing with the territorial waters of Sweden and naval ceremonials in the Swedish Navy; the decision made concerning visits to Sweden by foreign warships and military aircraft, and other documents necessary for dealing with problems connected with the entry of warships into the Baltic Sea straits and territorial waters of Denmark and Sweden.

English Channel and the Strait of Dover. The rules for navigation in the above straits outside the territorial waters of England and France were established by the 1958 Convention on the High Seas, by its general principles on the freedom of navigation and by the historically developed rules and customs. Warships and non-military ships sailing under the flag of any nation enjoy the right of freedom of navigation in these straits. The English section of the strait (English Channel) is recommended for sailing to and from London as well as from Dover. The French section of the strait (Pas de Calais) is recommended only for sailing to and from the ports on the French coast (Dunkerque, Boulogne, etc.).

Until the adoption of special international agreements, it is recommended that Commanding Officers of warships and Captains of merchant vessels follow the above rules of navigation in view of the heavy traffic in these straits.

Strait of Gibraltar. Warships and non-military vessels of all nations have the right of passage through this strait. No nation, either in time of peace or war, has the right to control or restrict the movement of ships or vessels in the strait since it connects the open (international) waters of the Mediterranean and the Atlantic Ocean.

Sanggar and La Perouse Straits. There are no international agreements on these straits. Sanggar does not overlap with the territorial waters of Japan. Both straits are free for warships and non-military /381
vessels of all nations.

Korean Strait. The rules for passing through the Korean Strait are not bound by any international agreements. The Korean Strait is open to navigation by warships and non-military vessels of all nations.

Straits of the Indonesian Archipelago (Sunda, Karimata, and Makassar Straits). The rules for navigation in these straits were defined by the 1960 National Law No. 4 of the government of Indonesia which states that all water areas around and between the islands are inland waters of Indonesia. The territorial waters of West Kalimantan are regions closed to navigation. The Riau archipelago, the Tarakan region and the Island Ve have been placed under the control of the naval forces of Indonesia. The territorial waters of the Gulf of Halong and part of the Bay of Amboyna are also regions closed to navi-

gation by all ships and vessels not belonging to Indonesia.

The inland sea waters of Indonesia are open for the innocent passage by foreign warships and non-military vessels.

Taiwan Strait. This strait does not overlap with the territorial waters of the Chinese People's Republic and the Island of Taiwan. There is free passage through the strait for warships and non-military vessels of all flags. However, by special notice on 5 April 1958 the Administration of the Island of Taiwan converted the above strait into a control zone in which foreign vessels must use the passage between the Island of Taiwan and the Pescadores Islands and keep east of the center of the Taiwan Strait. Vessels sailing along the western shore of the Pescadores Islands must notify Taiwan authorities in advance.

Hainan Strait. In the 1964 law* the Chinese People's Republic de-

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* For more details see Notices to Mariners, Publishing House of the Main Administration, Ministry of Defense of the USSR, No. 14, 3 April 1964.

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clared the waters of the Hainan Strait inland sea waters. There is a control zone managed by the strait's administration which is informed about all passages through the strait 48 hours before approaching the control zone; permission must be obtained by radio from the strait's /382
Administration. The report must include the nationality of the ship, her name, displacement, speed, hull color, mark on the stack, point of origin and destination of the ship as well as the time of departure from the point of origin. The exact time of entering the zone is communicated to the zone administration 24 hours before approaching the control zone (which is bounded on the east by the Mulantoy and Shangoy-hoy lighted buoys and on the west by the Lingao and Tszyao-veytszyao buoys).

All foreign ships that have obtained permission, enter and leave the strait along the center fairway during the daylight hours (from sunrise to senset). The use of radar is prohibited in the strait zone except in unusual cases, with the permission of the zone administration. Foreign warships may sail through the strait only by special authorization of the government of the Chinese People's Republic.

Strain of Magellan. There are legal rules governing navigation in this strait. Both shores of the strait belong to Chile. According to Chilean regulations it is recommended that all Captains of ships passing through the strait communicate the nationality of the ship, her

name and call signs when passing the lighted buoys set up on the Las Evangelistas islands, in the Bay of Felix, on the Capes of San Isidro, Posesion, and Virgenes as well as when passing other lighted buoys from which this information may be requested. Information about ports of origin and destination must also be communicated. Mandatory piloting is practiced in the strait, including piloting of warships. Requests for piloting are made 4 hours before arriving at Punt Arenas.

Section 13.6. International Canals

Suez Canal. The legal rules for navigation in the canal were established by the Convention signed in Constantinople in 1888 as well as by the national legislation of the Arab Republic of Egypt.

The canal is open in times of peace and war for the free passage of merchant vessels and warships without regard to nationality, on the basis of equality with respect to navigation and port fees and with respect to other conditions. Vessels with a draft that does not comply with the depth of the canal are not permitted to enter the canal. Not permitted are also those which have malfunctioning radio equipment, /383 improper arrangement of deck cargoes, defective searchlights for special night illumination, etc.

Twenty-four hours prior to the arrival of a vessel (ship) at the outer roadstead of Port Said or Suez (or as soon as the range is sufficiently close for carrying out radio communication) the Captains of all vessels (Commanding Officers of Ships) communicate the following information to their agents at the canal:

- name and nationality of the vessel (ship);

- whether the vessel (ship) is in transit or is calling at a port where it will load or unload cargo;

- time of arrival and duration of anchorage;

- the presence of transit passengers or passengers proceeding only to the Arab Republic of Egypt;

- the presence of inflammable cargoes, etc. (only for merchant ships);

- the need for supplies (bunker oil, water);

- the need for repairs requiring anchorage at the port for more than 12 hours.

Upon approaching the outer roadstead of Port Said and Suez (and during anchorage at these roadsteads) a watch must be posted at the radiotelephone to receive instructions on sailing through the canal or changing the anchorage site from the canal traffic service.

The radio station of the Canal Administration transmits messages on sailing through the canal by using call signals SUQ at a frequency of 420 kHz (714 m). Vessels communicate with the radio station at a frequency of 425 kHz (705 m) or 468 kHz (641 m). Arriving ships (and those in the roadsteads) communicate by radiotelephone with the port authority at Port Said (call signal, Port Said - 1) at a frequency of 2182 kHz; with the pilot ship by using the call signal "Pilot boat"; with the port authority by using the call signal "Port Said-4" at a frequency of 156.3 MHz (modulated oscillations); with Port Suez at a frequency of 157.3 MHz or 2102 kHz; and with Port Ismailia at 156.8 MHz or 2182 kHz.

It is recommended that ships in the roadstead of Port Suez, south of Green Island, take their stations in the following manner:

a) tankers with a cargo of crude oil and gasoline should position themselves in the eastern part of the roadstead, keeping the passage through the main channel free;

b) other vessels should assume their stations in the western part of the roadstead.

The first to sail from the Suez are the loaded tankers. One hour and 20 minutes later (after the last tanker has entered the canal) the following ships begin sailing:

- warships;

- tankers with tanks that have not been degassed;

- passenger ships;

- cargo vessels;

- vessels without steering wheel indicators and tachometers;

- vessels with low speed;

- vessels with malfunctioning machinery or steering gear;

At Port Said a convoy is formed at the ship mooring site. Warships and passenger vessels sail first, followed by the other vessels. The following distances are maintained in the convoy:

- between loaded tankers--2 km;

- between other vessels and warships--1 km.

The first convoy leaves Port Said, sailing south, between 0000 hours and 0002 hours; and the second convoy--between 0900 hours and 1200 hours.

Only one convoy per day, between 0600 and 2300 hours, sails north from Suez.

The convoy leaving Port Said at night sails without stopping, to the anchorage site in the southern part of Great Bitter Lake and remains there until the arrival of ships sailing north, following which the convoy continues on until it reaches the Gulf of Suez.

The daytime convoy from Port Said moors in the western part of the canal between the 51st and 61st km and remains there until the arrival of ships sailing north. It proceeds then, without stopping, until it leaves the canal.

The convoy leaving Suez anchors in the northern part of Great Bitter Lake until the arrival of the other convoy coming from Port Said at night.

The passing of convoys en route takes place in the Cabret Canal which is used by the convoy coming from the south.

The speed for all vessels and ships in the Suez Canal is 7.5 knots or 14 km/hr. For oil tankers it is 7 knots of 13 km/hr.

Piloting in Port Said. Port Taufiq Harbor and throughout the entire /385 length of the canal is mandatory for all ships whose total tonnage is more than 500 register tons. In Suez Bay and in the Port Suez area piloting is mandatory for all ships (warships and ships of the Arab Republic of Egypt and of the canal administration, not engaged in trade, as well as vessels with a load carrying capacity of up to 300 tons do not require piloting in this area).

Special permission is not required for making emergency stops by warships, but the Canal Administration must be informed of this and, if required, it can render the appropriate assistance.

Warships sail in convoys which are formed by the canal administration. As a rule, warships sail (at a speed of 7.5 knots) first in the convoy from Port Said to the south, while from Port Said to the north warships follow oil tankers (at a speed of 7 knots).

Warships of warring nations must pass through the canal in the

shortest possible time without stopping. The period of their stay in Port Said or in the Suez roadstead must not exceed 24 hours (except for emergency stops). The interval between the departure of a ship (vessel) of one belligerent nation and the departure of a ship (vessel) of the other belligerent nation must be more than 24 hours.

In the canal and at its entry ports warships have a right to obtain provisions and other supplies (ships and prizes of warring nations also have this right provided their needs are limited).

Panama Canal. The legal rules governing navigation through the canal were established by unilateral acts of the USA on the basis of the 1903 Treaty concluded between the USA and Panama. Non-military ships and warships nominally of all nations enjoy the right of free passage. However, in time of peace and war the USA reserves the right to refuse passage to foreign warships for reasons of security.

At the approaches to the canal all vessels hoist their call signs and at night communicate by means of signal lantern the name of the ship to the signal station.

An inspection of non-military vessels is conducted in the roadstead of Limon Bay as well as opposite the entrance into the deep channel from the Pacific Ocean.

The early arrival of a ship at the entrance does not give her the /386
priority right for passing through the canal. The priority right is enjoyed only by the regularly scheduled passenger ships (fifty passengers or more). Sailing through the canal is permitted by ships and vessels with a draft between 11.27 and 12 m. Piloting is mandatory for all warships and non-military vessels throughout the entire length of the canal and in all six of its locks. Dimensions of locks: 304x33.5 m. The time required to sail through is 17 hours. Fees ranging from 50 to 90 cents per registered ton are collected for passage.

The passage by warships requires the sending of a written notification to the US State Department or to the Governor of the Canal Zone, carrying detailed information on the time of arrival of the ship, her size, armament, and crew. Warships may carry out salutes only in the ports of Cristobal and Balboa.

Kiel Canal. The legal rules governing navigation in the canal were set by legislation of the Federal Republic of Germany, namely, by the Rules of Navigation in the Kiel Canal, including the Haselau Canal and the Achterwehrer-Schiffahrts Canal.

Vessels of all nations are permitted to use the canal at any time during the 24-hour period, after receiving special passes and paying tolls. Warships of foreign nations may enjoy the right of passage

through the canal after receiving (via diplomatic channels) an advanced consent of the government of the Federal Republic of Germany. Piloting is mandatory for all warships and non-military vessels. Towing and piloting with the aid of a pilot from the canal administration can be made mandatory on demand by the administration.

Vessels and warships with the following dimensions are permitted in the canal:

- draft, 9.5 m;

- beam, 40 m;

- length, 315 m;

- height of masts above the waterline, 40 m.

Vessels with poor maneuverability or with cargo that reduces stability and maneuverability are not permitted to sail in the canal.

The administration determines the passage priority for any one vessel. Movement in the canal is in both directions and continuous. The speed for vessels with a draft greater than 9 m is 12 km/hr and for other vessels--15 km/hr. Warships that have received permission from FRG authorities for passage have the absolute passage priority and en- /387
joy the right of immunity; however, the guns of ships must not be loaded.

Warships have the right to refuse the service of a pilot offered by the canal administration but piloting (or towing) remains mandatory for them. Under existing regulations it is prohibited to take pictures and make sketches or to engage in other activities violating the military security regulations of the country.

The length of the canal is about 95 km; width across the bottom--42 m; and the average depth in channels--11 m. For passing and turning there are special basins and 13 widened areas.

Corinth Canal. The legal rules governing navigation through the canal are established by legislation of Greece. The consent of the Greek government is required for sending foreign warships through the canal. There is a special agreement, concluded in 1953 between the USA and Greece, on the use of the canal by American ships and vessels.

The length of the canal, 3.5 miles; width, 22 m; and the depth, 8 m. The canal connects the Aegean Sea with the Gulf of Corinth and with the Ionian and Adriatic seas. It shortens the route for ships sailing from the Adriatic Sea by 186 miles and for those proceeding from the western part of the Mediterranean to the Aegean Sea by 93 miles.

Section 13.7. Instructions on the Use of Special Signals Provided by Article VI of the Agreement between the USA and the USSR on the Prevention of Incidents on the High Seas and in the Air Space above Them, of 25 May 1972 (Henceforward referred to as the Agreement)

I. General Provisions

1. The signals in the attached Table (special signals) supplement the signals contained in the International Code of Signals adopted by the IMCO in 1965.

2. The special signals whose meanings are not given in the International Code of Signals at the present time, may be used for indicating intentions or transmitting information between ships of the USA and the USSR, as provided in Article I of the Agreement. /388

II. Use of Signals

1. The general provisions of the instructions on the use of the International Code of Signals apply also to the use of the special signals as indicated below.

2. In order to avoid misunderstandings each signal in the supplementary Table must be preceded by the recognition group YVI, which means that the signal refers precisely to this Table.

3. The special signals may be transmitted by the same methods which are used for transmitting signals from the International Code of Signals, i.e., by hoisting flags, by means of signalling projectors, by Morse code or by means of the flag semaphore or other methods.

4. Certain special signals can be used to indicate distance, course, or time. Since the meaning of each special signal is exact, and in order to avoid confusion, groups must not be preceded by the designations of the code signals: R (distance), C (course), T (time).

Examples:

PT9-6. I will cross your course at a distance of 600 meters astern.

UY1-120. I am getting ready for the take-off or landing of aircraft with the true course 120°.

RU2-5. In about 5 minutes I will be turning to port.

5. Certain special signals can be used to indicate the direction

toward a hazard, reckoned from the ship transmitting the given signal. The direction is indicated by using Table III of the International Code of Signals.

Examples:

UY3-2. I am getting ready for practice firing of guns in the direction east of me. Please by cautious.

NB1-8. North of me I have hydrographic research equipment overboard not under tow.

6. The reception of special signals can be confirmed by means of the ZL1 signal, taken from the Table of Special Signals, or, if the signals are not understood, by means of signals ZL or ZQ taken from the International Code of Signals. /389

Special Signals

Distinguishing Signal YVI
(Group following is preceded by this signal)

Signal	Meaning of Signal
IR1	I am engaged in oceanographic work
IR2 (...)	I have overboard (I am towing) hydrographic research equipment __________ astern
IR3	I am hoisting on board hydrographic research equipment
IR4	I am engaged in rescue operations
JH1	I am trying to free a grounded vessel
MH1	Please do not cross my course
NB1 (...)	I have overboard hydrographic research apparatus not under tow in the direction __________ of me (Table III International Code of Signals)
PJ1	I cannot change course to starboard
PJ2	I cannot change course to port
PJ3	Caution, my steering system is out of order
PP8 (...)	Dangerous operations are being conducted. Request that you do not remain in the direction __________ of me (Table III International Code of Signals)

Signal	Meaning of Signal
QF1	I have stopped engines, please observe caution
QS6 (...)	I am heading for anchorage on a course ______
QV2	I am firmly secured by means of two or more anchors or mooring buoys at the bow and stern. Please do not create disturbances
QV3	I am at anchor at a great depth with hydrographic research equipment overboard /390
RT2	I intend to pass on your port side
RT3	I intend to pass on your starboard side
RT4	I will overtake you on your port side
RT5	I will overtake you on your starboard side
RT6 (...)	The formation is maneuvering. Request that you not remain in the direction ______ of me (Table III International Code of Signals)
RT7 (...)	I will approach starboard side of your ship at a distance of ______ hundred meters (yards)
RT8 (...)	I will approach port side of your ship at a distance of ______ hundred meters (yards)
RT9 (...)	I will pass you astern at a distance of ______ hundred meters (yards)
RU2 (...)	I will begin turning to port in about ______ minutes
RU3 (...)	I will begin turning to starboard in about ______ minutes
RU4	The formation is preparing to change course to port
RU5	The formation is preparing to change course to starboard
RU6	I am conducting training in maneuvering, it is dangerous to be inside of the formation
RU7	I am preparing to dive
RU8	A submarine will surface within two miles of me in no later than 30 minutes. Request that you do not interfere
SL2	Request that you indicate your course, speed, and intentions for passing

Signal	Meaning of Signal
TX1	I am engaged in fish surveillance /391
UY1 (...)	I am preparing to launch (land) an airplane on a course __________
UY2 (...)	I am preparing to conduct practice rocket firing. Request that you do not remain in the direction __________ of me (Table III International Code of Signals)
UY3 (...)	I am preparing to conduct practice gunfiring. Request that you do not remain in the direction __________ of me (Table III)
UY4	I am preparing to conduct (I am conducting) operations with the use of explosives
UY5 (...)	I am maneuvering to prepare for conducting practice torpedo firing in the direction from me as indicated __________(Table III International Code of Signals)
UY6 (...)	I am preparing for underway replenishment on a course __________
UY7	I am preparing to conduct a landing training exercise with the use of a large number of small landing craft
UY8	I am maneuvering in order to lower (retrieve) landing craft
UY9	I am preparing to conduct operations with helicopters over the stern
ZL1	I received and understood your signal
ZL2	Did you understand me? Please confirm.

CHAPTER 14

REFERENCE DATA

Section 14.1. Width of the Territorial Waters and Special Sea Zones of Some Coastal Nations (as of 1 September 1974)

State	Width of territorial waters and special zones, nautical miles (km)			
	Territorial waters	Fishing zone	Customs zone	Security zone
Australia	3	12	3	-
Albania	12	12	-	-
Algeria	12	-	-	-
Argentina	200	-	12	-
ARE	12	-	18	-
Bangladesh	12	-	-	-
Barbados	3	-	-	-
Bahrein	3	-	-	-
Belgium	3	12	(10)	-
Ivory Coast	6	12	(20)	-
Burma	12	-	-	-
Bulgaria	12	-	-	-
Brazil	200	-	-	-
Great Britain	3	12	3	-
Venezuela	12	-	15	15
Gabon	100	-	-	-
Haiti	6	(20)	-	-
Gaiana	3	-	-	-
Gambia	50	-	18	-
Ghana	30	130	-	-
Guatemala	12	-	12	-

State	Width of territorial waters and special zones, nautical miles (km)			
	Territorial waters	Fishing zone	Customs zone	Security zone
Guinea	130	142	-	-
Guinea-Bissau	6	-	-	-
GDR	3	-	3	-
Honduras	12	-	6	-
Greece	6	-	-	10
Dahomey	12	-	-	-
Denmark (including Greenland and the Faeroe Islands)	3	12[2]	4	-
Dominican Republic	6	12	12	12
DRV	12	-	-	-
Zaire	3	-	-	-
Israel	6	-	-	-
India	12	100[3]	12	-
Indonesia	12	-	-	-
Jordan	3	-	-	-
Iraq	12	-	-	-
Iran	12	10[4]	12	12
Ireland	3	12	-	-
Iceland	4	50	4	-
Spain	6	12	12	-
Italy	12	-	12	10
Yemen (Aden)	12	-	18	18
Yemen (Sana)	12	-	-	-
Cambodia	12	-	-	-
Cameroun	18	-	-	-
Canada	12	12[5]	9	100[7]
Kenya	12	-	-	-

State	Width of Territorial waters and special zones, nautical miles (km)			
	Territorial waters	Fishing zone	Customs zone	Security zone
Cyprus	12	-	-	-
Korean People's Dem. Rep.	12	-	-	-
Chinese People's Republic	12	-	12	-
Colombia	12	-	(20)	-
Congo (Brazzaville)	30	-	-	-
Costa Rica	12	200	-	-
Cuba	3	3	12	5[7]
Kuwait	12	-	-	-
LAR	12	-	10	-
Liberia	12	-	-	-
Lebanon	6	6	(20)	-
Maurice	12	-	-	-
Mauritania	30	-	-	18
Malagasy Republic	50	-	-	-
Malaysia	12	-	-	-
Maldive Republic	80 - 100	80 - 100	-	-
Malta	6	12	-	-
Morocco	12[8]	70[8]	-	-
Mexico	12	-	-	-
Monaco	12	-	-	-
Nigeria	30	-	-	-
Netherlands	3	12	-	-
Nicaragua	3	200	-	-
New Zealand	3	12	-	-
Norway	4	12	10	-
Oman (Sultanate of Oman)	12	50	-	-

State	Width of territorial waters and special zones, nautical miles (km)			
	Territorial waters	Fishing zone	Customs zone	Security zone
Pakistan	12	112[3]	-	-
Panama	200	-	-	-
Peru	200	-	-	-
Poland	3	12	6	6
Portugal	6	12	12	12
Rumania	12	-	-	-
El Salvador	200	-	12	12
Syrian Arab Republic	12	-	12	18
Saudi Arabia	12	-	18	18
Senegal	12	122	18	-
Singapore	3	-	-	-
Somali Republic	200	-	-	-
USSR	12	12[9]	-	-
Sudan	12	-	-	-
USA	3	12	12	-
Sierra Leone	200	-	-	-
Thailand	12	-	-	-
Tanzania	50	-	-	-
Togo	12	-	-	-
Trinidad and Tobago	12	-	-	-
Tunisia	12	-	-	-
Turkey	6[1]	12	-	-
Uruguay	200	-	12	-
Philippine Islands	3	-	-	-
Finland	4	-	6	-
France	12	-	(20)	6[10]
FRG	3	-	3	-

State	Width of territorial waters and special zones, nautical miles (km)			
	Territorial waters	Fishing zone	Customs zone	Security zone
Chile	200	-	(100)	(100)
Sweden	4	12	4	-
Sri Lanka	12	112[3]	6	-
Ecuador	200	-	-	-
Ethiopia	12	-	-	-
UAR	6	12	12	-
Yugoslavia	10	12	12	-
South Vietnam	3	(20)	12	-
South Korea	3[6]	-	-	-
Jamaica	12	-	-	-
Japan	3	12 (by the prefectures of Simane, Yamaguti, Fukuoka, Saga, and Nagasaki	-	-

Remarks:

[1] According to the principle of reciprocity (for example, for Soviet ships--12 miles).

[2] Near the Faeroe Islands.

[3] Concervation zone (zone of conservation of the living resources of the sea) is periodically established.

[4] Near the shores of the Caspian Sea.

[5] Along the Newfoundland coast there is a territorial sea; there is no fishing zone.

[6] Sixty miles from the coast there is the so-called Li-Sin-Man line or the Rhee line where customs, fishing control, as well as control

(Remarks, continued)

of overflights by aircraft is being implemented.

7 Zone prohibiting pollution of the sea.

8 In the Strait of Gibraltar--up to the center line.

9 Near the shores of the Caspian Sea--10 miles.

10 In the region of the ports of Cherbourg, Brest, Toulon, and Bizerte there are restricted zones of 6 miles.

Section 14.2. Seaway Characteristics in Various Water Basins /397

Sea	Wave height, m	Wave length, m	Period, sec
Atlantic:			
Central part	21	376	15.5
Southern part	15	400	-
Baltic Sea	2	-	-
Barents Sea	3.7	-	-
White Sea	2	15	6
Indian Ocean	15	230	-
Caspian Sea	2.9	24	8.5
Mediterranean Sea	9	250	-
Black Sea	2.5	10-30	7
Sea of Japan	5.6	100	-

Section 14.3. Height of Tides in Certain Water Basins

Sea	High tide, m	Sea	High tide, m
Baltic (Kiel)	0.07	Kara (Dikson)	0.3
Barents (Murmansk)	4.0	Laptev (Khatango)	2.0
White (Gulf of Mezen)	8.5	Okhotsk (Penzhina Bay)	11.0
White (Archangel)	0.9	North Sea	5.0-8.0
East Siberian (mouth of Kolyma River)	0.1	Black Sea (Poti)	0.08
		Sea of Japan	0.3-0.5

Section 14.4. Mean Temperature, Salinity, and Relative Transparency of water /398

Sea	Temperature, °C			Salinity, mean annual, °/oo		Relative transparency, m
	Surface		Mean annual bottom	Surface	Bottom	
	Mean winter	Mean summer				
Sea of Azov	1.6	32.0	-	11.0	17.8	-
Baltic	2.0	17.0	4.0	15.0	14.7	-
Barents	-1.9	up to 10.0	0-3	35	-	up to 45
White	-1.9	14.0	-1.5	25	33.5	6.5-11.0
Bering	-	10.0	1.0	30-32	-	-
Carribbean	27.0	27.0	4.2	35.0	-	-
Caspian	7.0	30.0	5.0	13.0	-	11-13
Red	21.0	32.0	22.0	40.0	40.7	-
Marmora	-	-	14.0	23.0	33.8	-
Sea of Okhotsk	-	12.0	-1.5	32.3	34.4	-
North	-	-	-	35.0	35.0	6.5-22
Mediterranean	13.0	25.0	13.0	39.0	38.7	50-60
Black	6.0	22.0	9.0	15-18	22.5	28
Chukchi	-1.8	2-8	-	-	-	-
Sea of Japan	0	27.0	0.1	34.0	34.5	-

Temperature °C	Salinity, $^o/oo$									
	0	2	5	10	15	20	25	30	35	40
-2	-	-	-	-	-	1.01604	1.02009	1.02415	1.02820	1.03227
-1	-	1.00146	1.00391	1.00797	1.01202	06	10	13	17	22
0	0.99986	53	397	1.00801	1.01204	1.01606	1.02008	1.02410	1.02813	1.03216
1	93	59	401	04	05	05	05	06	07	09
2	97	62	03	04	04	02	01	399	799	00
3	99	64	04	03	01	598	1995	93	91	190
4	1.00000	64	03	00	197	93	88	84	81	79
5	0.99999	1.00162	1.00401	1.00796	1.01192	1.01586	1.01920	1.02374	1.02770	1.03166
6	97	59	397	91	85	77	70	63	57	53
7	93	55	91	84	76	68	57	51	44	38
8	88	49	85	76	67	57	47	38	29	22
9	81	42	76	67	56	45	34	23	14	06
10	0.99973	1.00133	1.00367	1.00756	1.01144	1.01532	1.01919	1.02308	1.02697	1.03088
11	63	23	56	44	31	18	04	291	79	69
12	52	12	44	31	17	02	888	74	61	49
13	40	099	31	17	01	486	70	55	41	29
14	27	85	17	01	085	68	52	36	20	07
15	0.99913	1.00070	1.00301	1.00685	1.01067	1.01450	1.01832	1.02215	1.02599	1.02985

Density of Seawater, g/cm^3 (continued)

Temperature °C	Salinity, $^o/oo$									
	0	2	5	10	15	20	25	30	35	40
16	1.99897	1.00054	1.00284	1.00667	1.01049	1.01430	1.01811	1.02193	1.02577	1.02961
17	80	37	67	48	29	09	790	71	53	37
18	62	19	48	28	08	388	67	48	29	12
19	43	0.99999	28	07	0986	65	44	23	04	886
20	0.99823	0.99980	1.00207	1.00586	1.00964	1.01342	1.01720	1.02098	1.02478	1.02859
21	02	57	1.00185	63	40	17	1.01694	72	51	32
22	0.99780	35	62	39	15	1.01292	68	45	24	04
23	56	11	38	14	890	65	41	18	395	775
24	32	869	13	488	63	38	13	1989	66	50
25	0.99707	0.99861	1.00087	1.00461	1.00836	1.01210	1.01585	1.01960	1.02336	1.02714
26	681	35	60	34	08	181	55	30	05	683
27	54	07	32	06	778	51	25	899	2274	51
28	26	779	03	376	48	21	493	69	42	18
29	597	50	0.99974	46	18	089	61	34	08	585
30	0.99567	0.99720	0.99943	1.00315	1.00686	1.01057	1.01428	1.01801	1.02175	1.02550

Wind force		Wind velocity at height 6 - 8 m, m/sec	Visible signs of wind observed on board ship	State of the sea surface with wind induced waves		
Beaufort No.	Description			Description	State of sea, points	Signs for determining force of true wind and the level of wind waves
0	Calm	0.0 - 0.5	Flags motionless	Completely calm sea	0	Mirror-smooth sea
1	Light air	0.6 - 1.7		Calm sea	1	Ripples
2	Light breeze	1.8 - 3.3	Flags sway slightly	Scarcely noticeable disturbance	1 - 2	Small scale-like waves neither breaking nor foaming
3	Gentle breeze	3.4 - 5.2	Flags flap	Light waves	2	Short well-defined waves. Breaking crests form glassy foam; occasionally small whitecaps appear
4	Moderate breeze	5.3 - 7.4	Small flags and pennants extend out	Weak waves	3	Waves lengthen; crest breaks more often; whitecaps visible in many places /402
5	Fresh breeze	7.5 - 9.8	Large flags extend out	Moderate waves	4	Waves well-developed in length but not very large

Force and Velocity of Wind and Sea States (continued)

Wind force		Wind velocity at height 6 - 8 m, m/sec	Visible signs of wind observed on board ship	State of the sea surface with wind induced waves		
Beaufort No.	Description			Description	State of sea, points	Signs for determining force of true wind and the level of wind waves
6	Strong breeze	9.9 - 12.4	Whistling in the rigging	Considerable waves	5	Sea completely covered with whitecaps. Large waves begin to form. White foaming crests occupy large areas
7	Moderate gale	12.5 - 15.2	Whistling in the rigging increases steadily	Great waves	6	Waves pile up, crests break, foam lies in streaks, blown by the wind /403
8	Fresh gale	15.3 - 18.2	Moving against the wind on deck difficult	Strong waves	7	Waves become mountainous, with rather long crests. Along edges of crests sea spray begins to form. Dense streaks of foam form in the direction of the wind. At times the waves roar

Force and Velocity of Wind and Sea States (continued) /404

Wind force		Wind velocity at height 6 - 8 m, m/sec	Visible signs of wind observed on board ship	State of the sea with wind induced waves		
Beaufort No.	Description			Description	State of sea, points	Signs for determining force of true wind and the level of wind waves
9 10	Strong gale Whole gale	18.3 - 21.5 21.6 - 25.1	Moving against the wind on deck difficult	Violent waves	8	Very high mountain-like waves with long breaking crests. Foam, driven by the wind, forms broad dense strips. Roar of waves becomes powerful and resembles pounding. Surface of sea becomes white with foam. Visibility is impaired by spray.
11 12	Storm Hurricane	25.2 - 29.0 more than 29.0	Moving against the wind on deck difficult	Mountainous waves	9	Waves are so high that at times ships dissappear from view. Everywhere edge of crests burst into clouds of spray. Sea is completely covered with streaks of foam. The wind, breaking the wave crests, carries away the foam and spray, filling the air and significantly reducing visibility.

Section 14.7. Table of Speeds /405

Knots					Kilometers per hour				
Knots	Cable lengths/min	m/sec	m/min	km/hr	km/hr	Cable lengths/min	Knots	m/sec	m/min
1	0.17	0.51	30.9	1.85	1	0.09	0.54	0.28	16.7
2	0.33	1.03	61.7	3.70	2	0.18	1.08	0.56	33.3
3	0.50	1.54	92.6	5.56	3	0.27	1.62	0.83	50.9
4	0.67	2.06	123.5	7.41	4	0.36	2.16	1.11	66.7
5	0.83	2.57	154.3	9.26	5	0.45	2.70	1.39	83.3
6	1.00	3.09	185.2	11.11	6	0.54	3.24	1.67	100.0
7	1.17	3.60	216.1	12.96	7	0.63	3.78	1.94	116.7
8	1.33	4.12	246.9	14.82	8	0.72	4.32	2.22	133.3
9	1.50	4.63	277.8	16.67	9	0.81	4.86	2.50	150.0
10	1.67	5.14	308.7	18.52	10	0.90	5.40	2.78	166.7
11	1.83	5.66	339.5	20.37	11	0.99	5.94	3.06	183.3
12	2.00	6.17	370.4	22.22	12	1.08	6.48	3.33	200.0
13	2.17	6.69	401.3	24.08	13	1.17	7.02	3.61	216.7
14	2.33	7.20	432.1	25.93	14	1.26	7.56	3.89	233.3
15	2.50	7.72	463.0	27.78	15	1.35	8.10	4.17	250.6
16	2.67	8.23	493.9	29.63	16	1.44	8.64	4.44	266.7 /406
17	2.83	8.75	524.7	31.48	17	1.53	9.18	4.72	283.3
18	3.00	9.26	555.6	33.34	18	1.62	9.72	5.00	300.0
19	3.17	9.77	586.5	35.19	19	1.71	10.26	5.28	316.7
20	3.33	10.29	617.3	37.04	20	1.80	10.80	5.56	333.3

Table of Speeds (continued)

Knots

Knots	Cable lengths/min	m/sec	m/min	km/hr
21	3.50	10.80	648.2	38.89
22	3.67	11.32	679.1	40.74
23	3.83	11.83	709.9	42.60
24	4.00	12.35	740.8	44.45
25	4.17	12.86	771.7	46.30
26	4.33	13.38	802.5	48.15
27	4.50	13.90	833.4	50.00
28	4.67	14.40	864.3	51.86
29	4.83	14.92	895.1	53.71
30	5.00	15.43	926.0	55.56

Kilometers per hour

km/hr	Cable lengths/min	Knots	m/sec	m/min
21	1.89	11.34	5.83	350.0
22	1.98	11.88	6.11	366.7
23	2.07	12.42	6.39	383.3
24	2.16	12.96	6.67	400.0
25	2.25	13.50	6.94	416.7
26	2.34	14.04	7.22	433.3
27	2.43	14.58	7.50	450.0
28	2.52	15.12	7.78	466.7
29	2.61	15.66	8.06	483.3
30	2.70	16.20	8.33	500.0

Section 14.8. Conversion of Nautical Miles into Kilometers

/407

Nautical miles	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0	0.185	0.370	0.556	0.741	0.926	1.111	1.296	1.482	1.667
1	1.852	2.037	2.222	2.408	2.593	2.778	2.963	3.148	3.334	3.519
2	3.704	3.889	4.074	4.260	4.445	4.630	4.815	5.000	5.186	5.371
3	5.556	5.741	5.926	6.112	6.297	6.482	6.667	6.582	7.038	7.223
4	7.408	7.593	7.778	7.964	8.149	8.334	8.519	8.704	8.890	9.075
5	9.260	9.445	9.630	9.816	10.001	10.186	10.371	10.556	10.742	10.927
6	11.112	11.297	11.482	11.668	11.853	12.038	12.223	12.408	12.594	12.779
7	12.964	13.149	13.334	13.520	13.705	13.890	14.075	14.260	14.446	14.631
8	14.816	15.001	15.186	15.372	15.557	15.742	15.927	16.112	16.298	16.483
9	16.668	16.853	17.038	17.224	17.409	17.594	17.779	17.964	18.150	18.335

Section 14.9. Conversion of Kilometers into Nautical Miles /408

Kilometers	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0	0.054	0.108	0.162	0.216	0.270	0.324	0.378	0.432	0.486
1	0.540	0.594	0.648	0.702	0.756	0.810	0.864	0.918	0.972	1.026
2	1.080	1.134	1.188	1.242	1.296	1.350	1.404	1.458	1.512	1.566
3	1.620	1.674	1.728	1.782	1.836	1.890	1.944	1.998	2.052	2.106
4	2.160	2.214	2.268	2.322	2.376	2.430	2.484	2.538	2.592	2.646
5	2.700	2.754	2.808	2.862	2.916	2.970	3.024	3.078	3.132	3.186
6	3.240	3.294	3.348	3.402	3.456	3.510	3.564	3.618	3.672	3.726
7	3.720	3.834	3.888	3.942	3.996	4.050	4.104	4.158	4.212	4.266
8	4.320	4.374	4.428	4.482	4.536	4.590	4.644	4.698	4.752	4.806
9	4.860	4.914	9.968	5.022	5.076	5.130	5.184	5.238	5.292	5.346

Section 14.10. Correspondence Between Various Units for Measuring Length /409

Unit of length	Nautical mile	Cable Length	Meter	Yard	Foot	Inch
Nautical mile	-	10	1852	2026.66	6080	72960
English mile	0.869	8.687	1609	1760	5280	63346
Kilometer	0.54	5.4	1000	1093.61	3280.83	39370.08
Cable length	0.1	-	185.2	202.66	608	7296
Fathom (7 ft)	0.00116	0.0116	2.1336	2.3331	7	84
Fathom (6 ft)	0.00098	0.0098	1.8288	2	6	72
Meter	0.00054	0.0054	-	1.094	3.28	39.37
Yard	0.000493	0.0049	0.9144	-	3	36
Foot	0.000164	0.00164	0.3048	0.333	-	12
Inch	0.0000137	0.000137	0.0254	0.0277	0.0833	-
Centimeter	0.0000054	0.000054	0.01	0.01093	0.032808	0.3937
Millimeter	0.00000054	0.0000054	0.001	0.00109	0.00328	0.03937

Note. The English round off the cable length and consider it equal to 200 yards (600 ft) or 100 fathoms (the 6-foot fathom).

Section 14.11. Compass Points in Degrees

Point No.	Point Desig-nation	No. of degrees in quadrant system	No. of degrees in angular measure	Point No.	Point Desig-nation	No. of degrees in quadrant system	No. of degrees in angular measure
0	N	NO°	0°	16	S	SO°	180°
1	NtO	$11^1/_4$	$11^1/_4$	17	StW	$11^1/_4$	$191^1/_4$
2	NNO	$22^1/_2$	$22^1/_2$	18	SSW	$22^1/_2$	$202^1/_2$
3	NOtN	$33^3/_4$	$33^3/_4$	19	SWtS	$33^3/_4$	$213^3/_4$
4	NO	NO45°	45°	20	SW	SW45°	225°
5	NOtO	$56^1/_4$	$56^1/_4$	21	SWtW	$56^1/_4$	$236^1/_4$
6	ONO	$67^1/_2$	$67^1/_2$	22	WSW	$67^1/_2$	$247^1/_2$
7	OtN	$78^3/_4$	$78^3/_4$	23	WtS	$78^3/_4$	$258^3/_4$
8	O	0st90°	90°	24	W	W90°	270°
9	OtS	$78^3/_4$	$101^1/_4$	25	WtN	$78^3/_4$	$281^1/_4$
10	OSO	$67^1/_2$	$112^1/_2$	26	WNW	$67^1/_2$	$292^1/_2$
11	SOtO	$56^1/_4$	$123^3/_4$	27	NWtW	$56^1/_4$	$303^3/_4$
12	SO	SO45°	135°	28	NW	NW45°	315°
13	SOtS	$33^3/_4$	$146^1/_4$	29	NWtN	$33^3/_4$	$326^1/_4$
14	SSO	$22^1/_2$	$157^1/_2$	30	NNW	$22^1/_2$	$337^1/_2$
15	StO	$11^1/_4$	$168^3/_4$	31	NtW	$11^1/_4$	$348^1/_4$
				32	N	0°	360°

Section 14.12. Range of Visible Horizon D_e And Radar Horizon D_r

/411

Height*, m	D_e, miles	D_r, miles	Height*, m	D_e, miles	D_r, miles
0.0	0.0	0.0	16.0	8.3	8.9
0.25	1.0	1.1	17.0	8.6	9.2
0.5	1.5	1.6	18.0	8.8	9.4
0.75	1.8	1.9	19.0	9.1	9.7
1.0	2.1	2.2	20.0	9.3	9.9
2.0	2.9	3.1	21.0	9.5	10.2
2.5	3.3	3.5	22.0	9.8	10.5
3.0	3.6	3.8	23.0	10.0	10.7
4.0	4.2	4.5	24.0	10.2	10.9
5.0	4.7	5.0	25.0	10.4	11.1
6.0	5.1	5.4	30.0	11.4	12.2
7.0	5.5	5.9	35.0	12.3	13.2
8.0	5.9	6.3	40.0	13.2	14.1
9.0	6.2	6.6	45.0	14.0	14.9
10.0	6.6	7.0	50.0	14.7	15.7
11.0	6.9	7.4	60	16.1	17.2
12.0	7.2	7.7	70	17.4	18.6
13.0	7.5	8.0	80	18.6	19.9
14.0	7.8	8.3	90	19.7	21.1
15.0	8.1	8.6	100	20.8	22.2
120	22.8	24.4	1100	69.0	73.8 /412
140	24.6	26.3	1200	72.1	77.1
160	26.3	28.1	1300	75.0	80.2
180	27.9	29.8	1400	77.8	83.2
200	29.4	31.4	1500	80.6	86.2
250	32.9	35.2	1800	88.3	94.4
300	36.0	38.5	2000	93.0	99.5
350	38.9	41.6	3000	113.9	121.8
400	41.6	44.5	4000	131.6	140.7
500	46.5	49.7	5000	147.1	157.3
600	51.0	54.5	6000	161.1	172.3
700	55.0	58.8	7000	174.0	186.1
800	58.9	63.0	8000	186.0	198.9
900	62.4	66.7	9000	197.3	211.0
1000	65.8	70.3	10000	208.0	224.4

* The height of the eye of the observer or radar antenna above sea level

Constant	Logarithm	Constant	Logarithm
$\mathrm{Mod} = \lg e = 0{,}43429$	9,63778	$\frac{1}{\pi} = 0{,}31831$	9,50285
$e = 2{,}71828$	0,43429	$C^\circ = 360^\circ$	2,55630
$\rho^\circ = \frac{180}{\pi} = 57{,}29578$	1,75812	$C' = 21600$	4,33445
$\rho' = \frac{10800}{\pi} = 3437{,}74677$	3,53627	$C'' = 1296000$	6,11261
$\rho'' = \frac{64800}{\pi} = 20626{,}498$	5,31443	$\sin 1^\circ = 0{,}017452$	8,24186
$\mathrm{arc}\, 1^\circ = \frac{2\pi}{360} = 1 : \rho^\circ = 0{,}017453$	8,24188	$\sin 1' = 0{,}00029089$	6,46373
$\mathrm{arc}\, 1' = \frac{2\pi}{360\times 60} = 1 : \rho' = 0{,}00029089$	6,46373	$\sin 1'' = 0{,}0000048481$	4,68557
$\mathrm{arc}\, 1'' = \frac{2\pi}{360\times 60\times 60} = 1 : \rho'' = 0{,}0000048481$	4,68557	$\sqrt{2} = 1{,}41421$	0,15051
$\pi = 3{,}14159$	0,49715	$\sqrt{3} = 1{,}73205$	0,23856
$\pi^2 = 9{,}86960$	0,99430	$\sqrt{1/2} = 0{,}70711$	9,84949
$\sqrt{\pi} = 1{,}77245$	0,24857	$\sqrt{1/3} = 0{,}57735$	9,76144
		$\sqrt[3]{2} = 1{,}25992$	0,10034
		$\sqrt[3]{3} = 1{,}44225$	0,15904
		$\sqrt[3]{1/2} = 0{,}79370$	9,89966
		$\sqrt[3]{1/3} = 0{,}69336$	9,84096

Section 14.14. Alphabets

/414

Latin		Greek	
Aa	Nn	Αα	Νν
Bb	Oo	Ββ	Ξξ
Cc	Pp	Γγ	Οο
Dd	Qq	Δδ	Ππ
Ee	Rr	Εε	Ρρ
Ff	Ss	Ζζ	Σσ
Gg	Tt	Ηη	Ττ
Hh	Uu	Θθ, ϑ	Υυ
Ii	Vv	Ιι	Φφ
Jj	Ww	Κκ	Χχ
Kk	Xx	Λλ	Ψψ
Ll	Yy	Μμ	Ωω
Mm	Zz		

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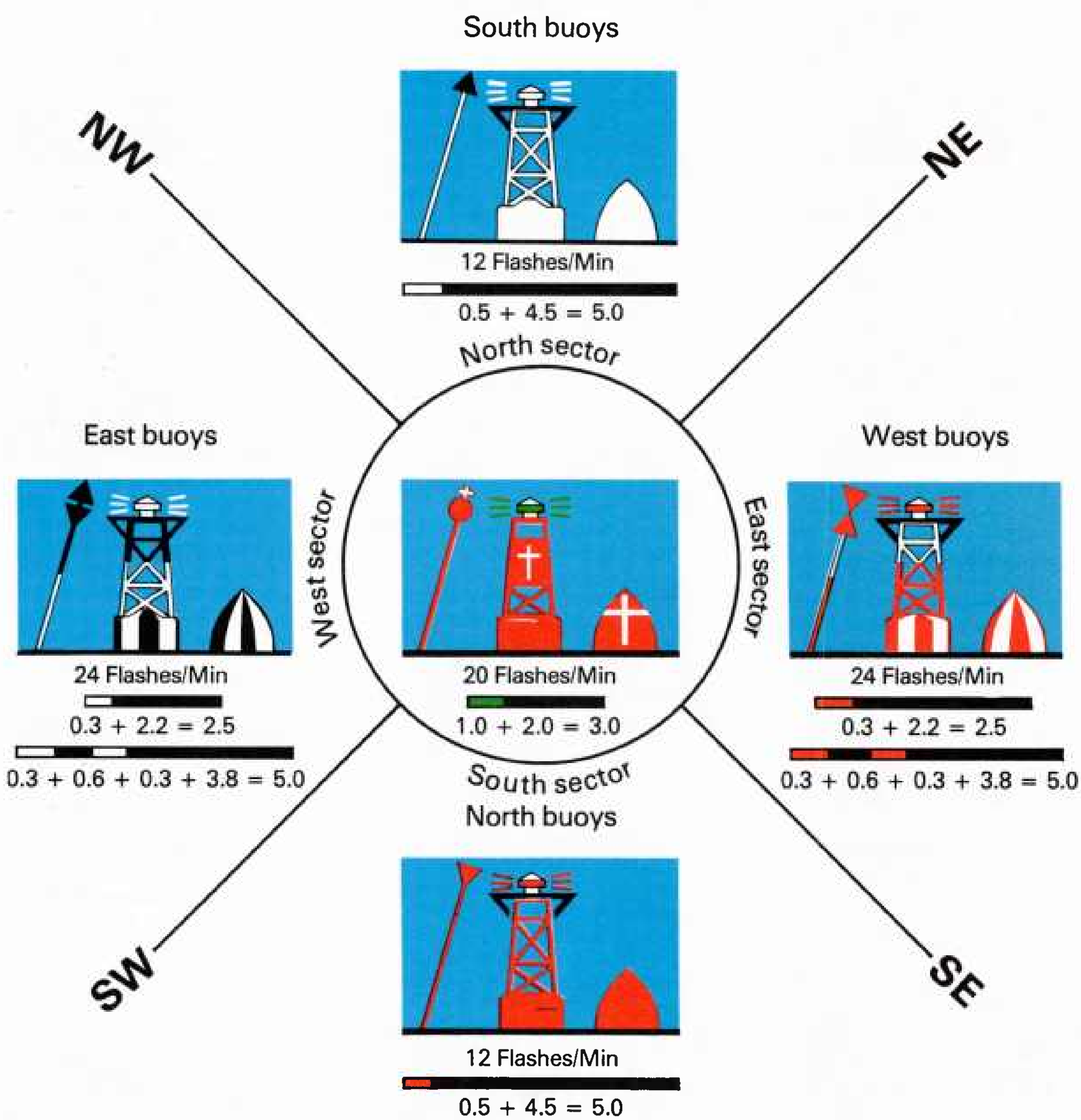
APPENDICES

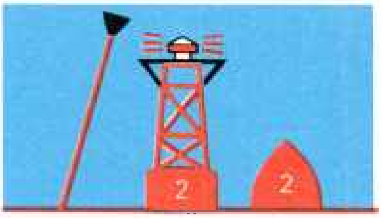
APPENDIX 1

CARDINAL SYSTEM OF MARKING NAVIGATIONAL DANGERS



BUOYS FOR MARKING CHANNELS, FAIRWAYS AND RECOMMENDED COURSES

Port hand buoys



20 Flashes/Min

0.5 + 2.5 = 3.0

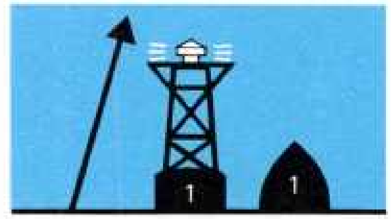
0.5 + 1.0 + 0.5 + 4.0 = 6.0

20 Flashes/Min

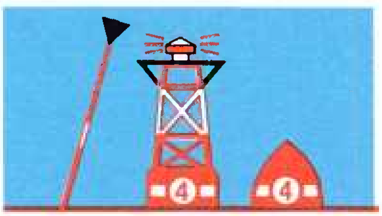
0.5 + 2.5 = 3.0

0.5 + 1.0 + 0.5 + 4.0 = 6.0

Starboard hand buoys



Turning port hand buoys



40 Flashes/Min

0.5 + 1.0 = 1.5

0.3 + 0.6 + 0.3 + 1.8 = 3.0

40 Flashes/Min

0.5 + 1.0 = 1.5

0.3 + 0.6 + 0.3 + 1.8 = 3.0

Turning starboard hand buoys

Bifurcation and junction buoys

10 Flashes/Min

2.0 + 4.0 = 6.0

Midchannel buoys

12 Flashes/Min

0.5 + 4.5 = 5.0

Turning midchannel buoys

30 Flashes/Min

0.5 + 1.5 = 2.0

0.5 + 0.5 + 0.5 + 2.5 = 4.0

Anchorage buoys

20 Flashes/Min

0.5 + 2.5 = 3.0

Wreck buoys

12 Flashes/Min

0.5 + 4.5 = 5.0

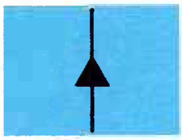
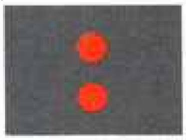
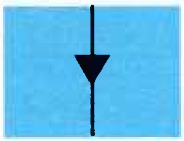
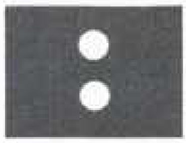
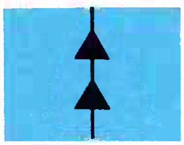
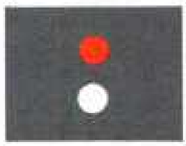
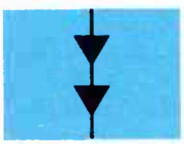
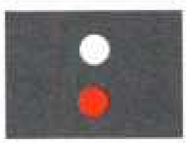
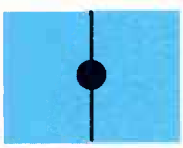
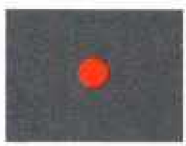
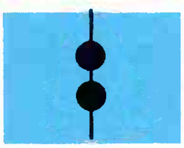
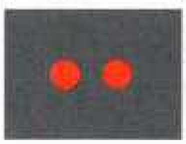
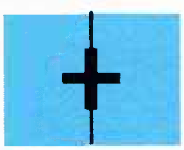
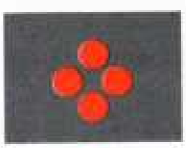
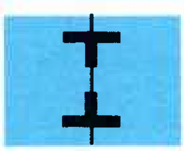
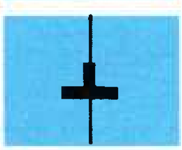
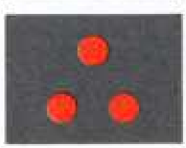
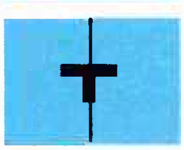
1.0 + 2.0 + 1.0 + 6.0 = 10.0

Quarantine buoys

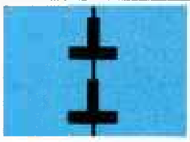
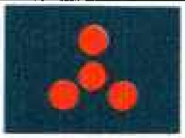
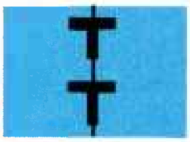
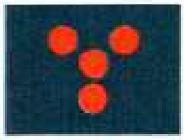
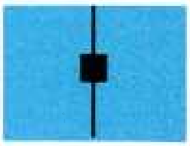
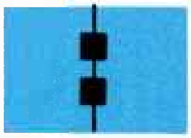
12 Flashes/Min

0.5 + 4.5 = 5.0

STORM AND STRONG WIND SIGNALS

No. of Signal	Type of Signal		Meaning of Signal
	Daytime	Nighttime	
1			Storm expected from NW
2			Storm expected from SW
3			Storm expected from NE
4			Storm expected from SE
5			Wind of 6-7 expected
6			Strong squall expected
7			Hurricane expected
8			Wind of 5 expected at sea or 4-5 in lakes and reservoirs
9			NW wind expected
10			SW wind expected

APPENDIX 3 (Cont'd)

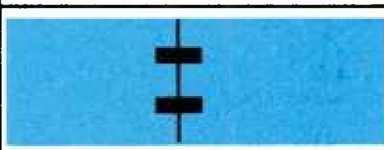
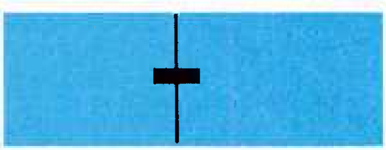
No. of Signal	Type of Signal		Meaning of Signal
	Daytime	Nighttime	
11			NE wind expected
12			SE wind expected
13			Wind veering expected
14			Wind backing expected

NOTES:

1. Signal no. 8 is displayed only in regions frequented by small vessels for which such a wind is dangerous.
2. If an increase in wind up to 8 points or more is expected, signals no. 5 and 8 with signals no. 9-12 are changed to signals no. 1-4 or 6-7 with signals 9-12.
3. Signals no. 13 and 14 are displayed with signals no. 1-4 and, when necessary, with one of the signals no. 9-12.

APPENDIX 4

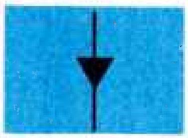
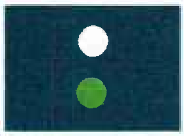
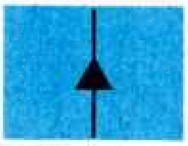
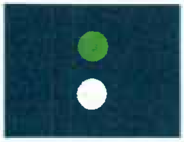
SIGNALS INDICATING THE TIME OF THE EXPECTED WEATHER CHANGE

No. of Signal	Type of Signal	Meaning of Signal
15		The predicted weather is expected tomorrow
16		The predicted weather is expected today

NOTES:

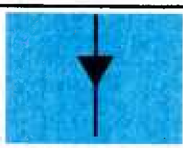
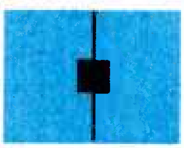
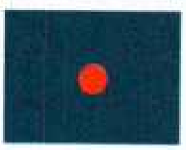
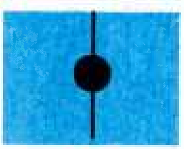
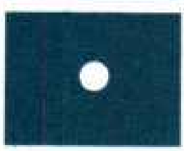
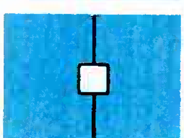
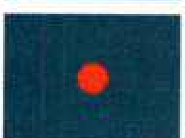
1. Signals no. 15 and 16 are displayed only in daytime together with one of the signals no. 1-12 given in Appendix 3.
2. The absence of time signals with one of the displayed signals no. 1-12 indicates that the predicted weather is expected within the next 12 hours.

HIGH TIDE AND LOW TIDE SIGNALS IN PORT

No. of Signal	Type of Signal		Meaning of Signal
	Daytime	Nighttime	
1			Low tide
2			High tide

NOTE: Cones used for signals nos. 1 and 2 should have a base diameter of 0.5 m and a height of 1.5 m.

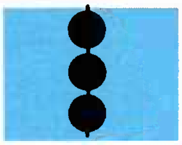
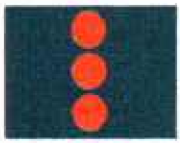
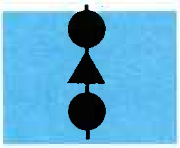
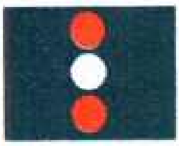
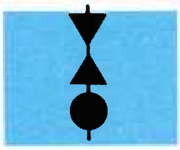
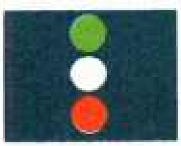
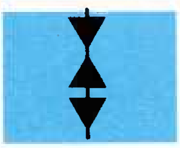
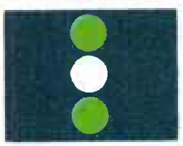
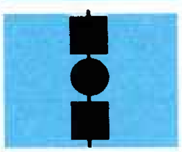
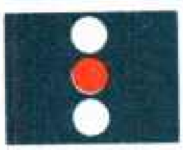
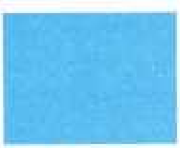
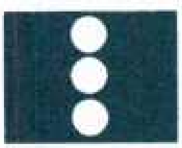
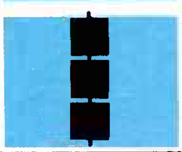
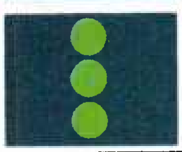
WATER HEIGHT SIGNALS

No. of Signal	Type of Signal		Meaning of Signal
	Daytime	Nighttime	
3			Water height is equal to 1 unit (20 cm)
4			Water height is equal to 5 units (1 m)
5			Water height is equal to 25 units (5 m)
6			Water height is equal to ½ unit (10 cm)

NOTE: The height and diameter of cones and cylinders as well as the diameter of balls (signals no. 3-6) should be no less than 1 m.

APPENDIX 6

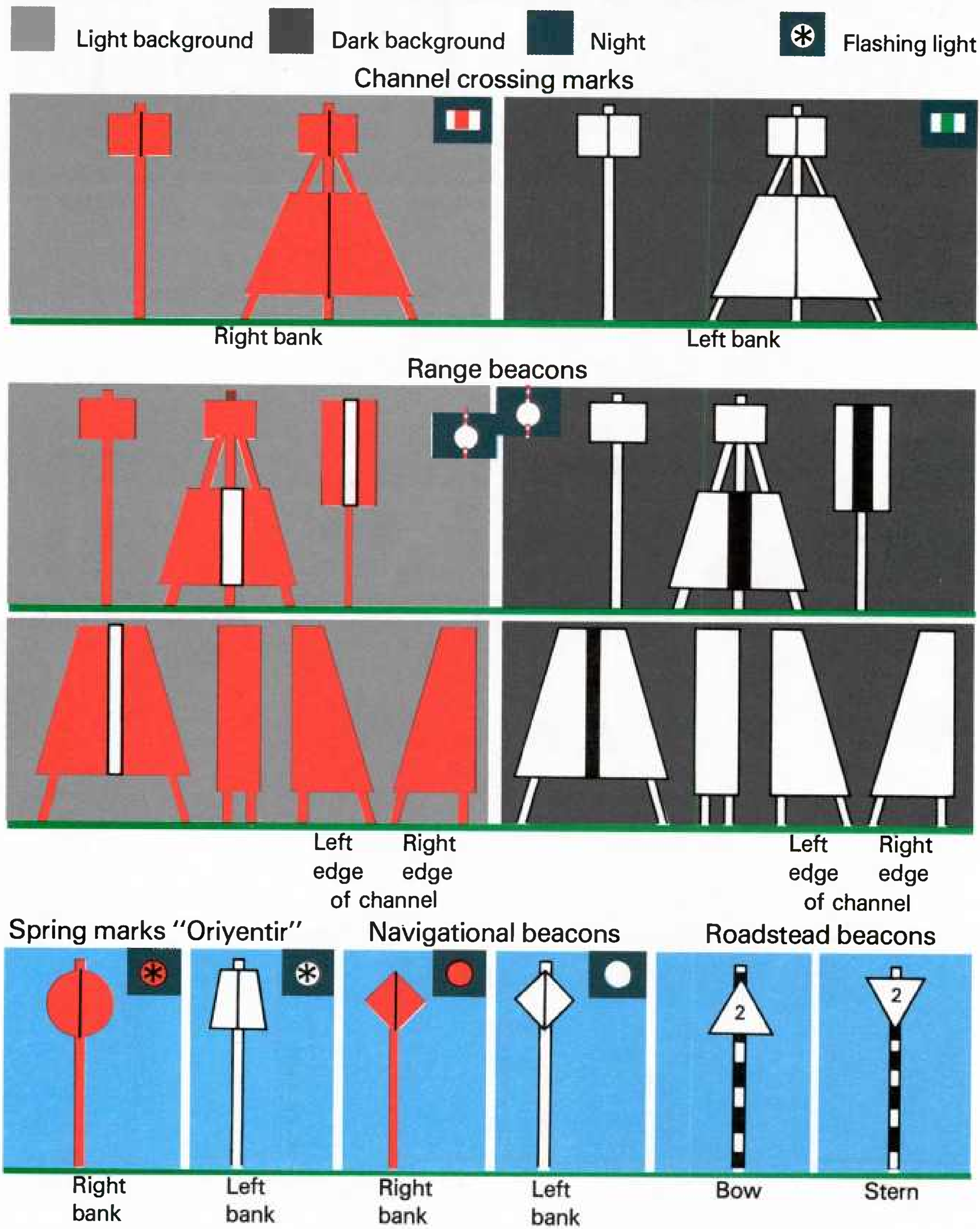
SIGNALS FOR SAILING IN HARBORS AND ROADSTEADS

No. of Signal	Type of Signal		Meaning of Signal
	Daytime	Nighttime	
7			Entry absolutely prohibited if there are serious accidents (such as blockage of the fairway by a ship run aground, etc.)
8			Entry prohibited under normal port operating conditions (only ships leaving port are permitted in the fairway)
9			No ship may enter or leave under normal port operating conditions (a compound dredger is passing)
10			No ship may leave under normal port operating conditions (only ships entering port are permitted in the fairway)
11			Unseaworthy ships, launches, and boats are prohibited in harbors and roadsteads
12			Boom defense gate is open
13			No warships, vessels, or harbor watercraft are permitted sailing in harbors and roadsteads

NOTES:

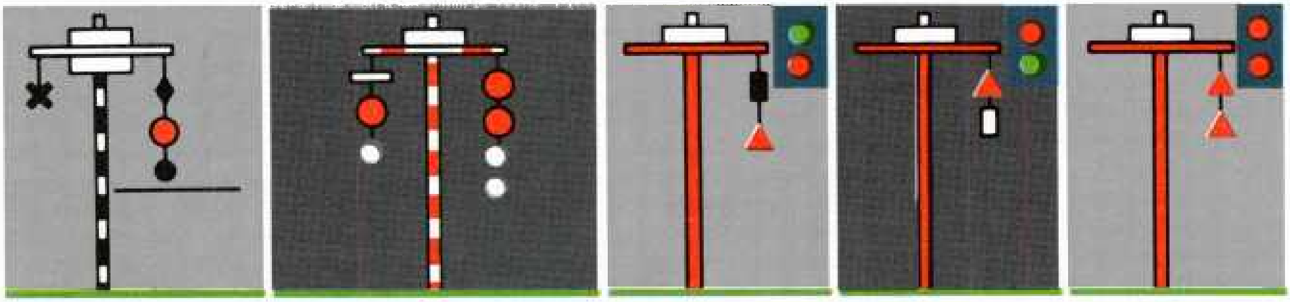
1. For signals nos. 7-11 the height and diameter of cones and cylinders should be no less than 1 meter.
2. The distance between daytime signal signs should be no less than 1 m and the distance between nighttime signal signs — no less than 2 m.
3. Signals no. 12 and 13 are in effect in the red banner Black Sea Fleet.

NAVIGATIONAL AIDS IN RIVERS, RESERVOIRS AND CANALS



APPENDIX 8

Channel marking mast | Shoal marking mast | Semaphore | M A S T S



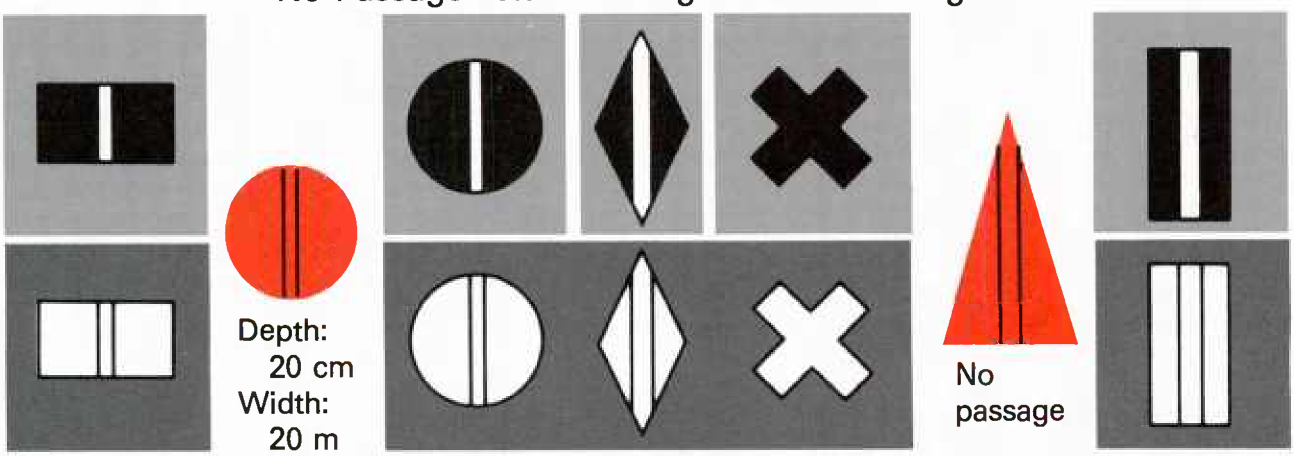
Depth marks displayed from upstream yardarm and width marks from downstream yardarm

Passage permitted for ships steaming downstream

Passage permitted for ships steaming upstream

Passage prohibited

Channel Depth and Width Marks "No Passage" and "Passage Permitted" Signals



Depth 1 m

Depth: 20 cm Width: 20 m

Depth: 5 cm Width: 20 m

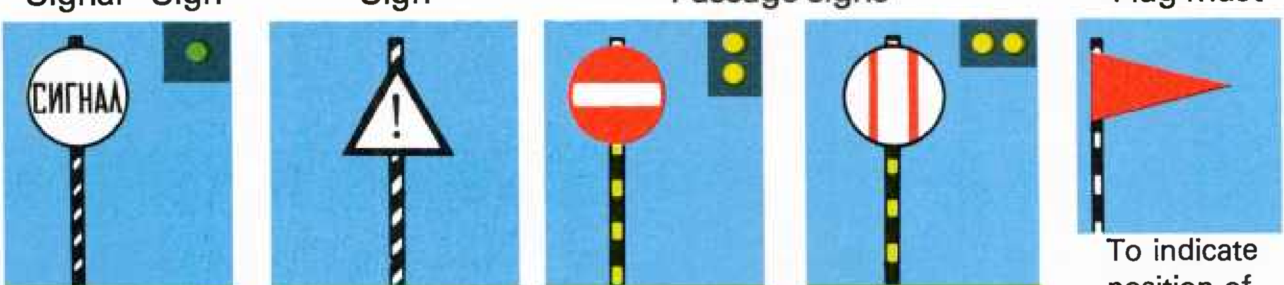
Width: 50 m

Depth exceeds the deepest draft of ships

No passage

Passage permitted

"Signal" Sign | "Attention" Sign | Passage signs | Flag mast



Give sound signal

Be careful

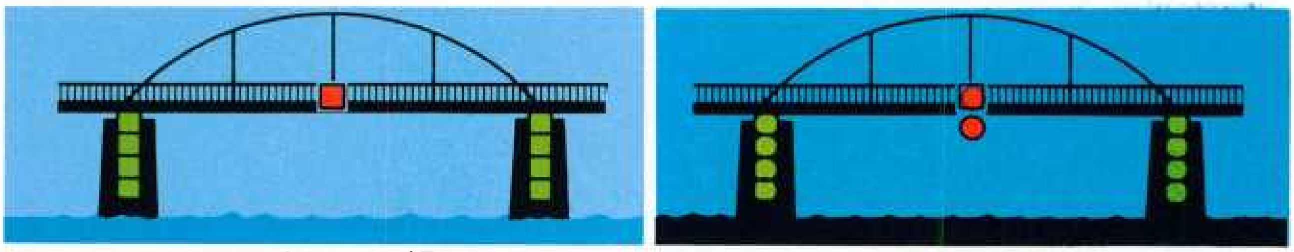
Underwater

Surface

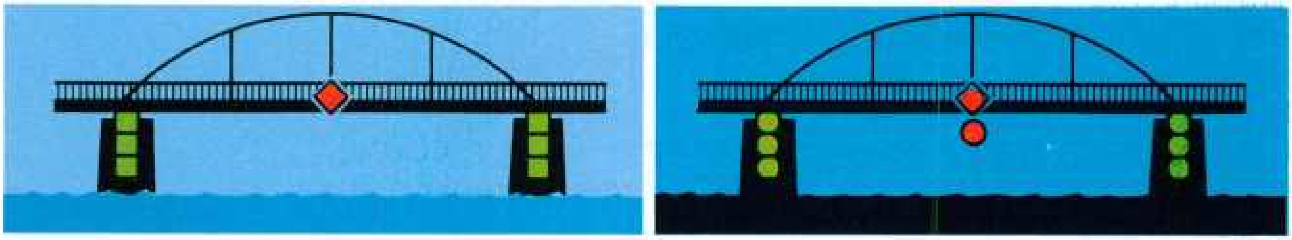
To indicate position of observation station

LIGHTS AND SIGNS ON BRIDGES

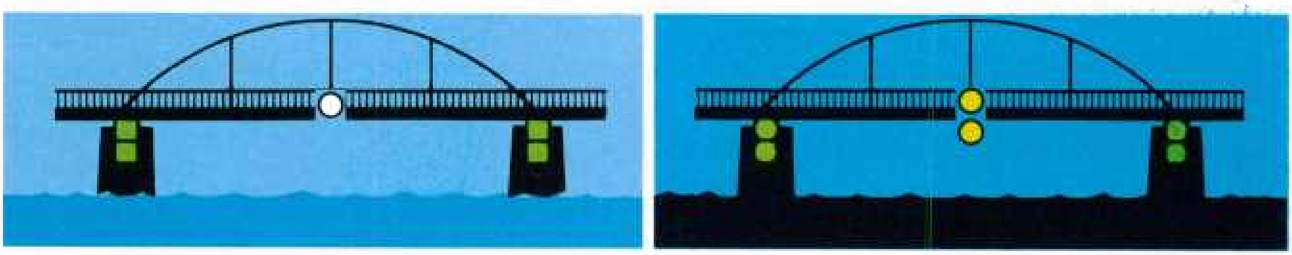
Daytime signals | Nighttime signals



Passage upstream - clearance 15 m

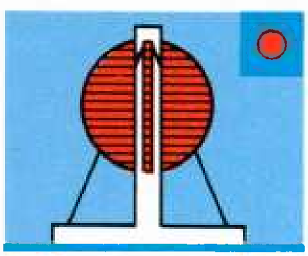


Passage downstream - clearance 10-15 m

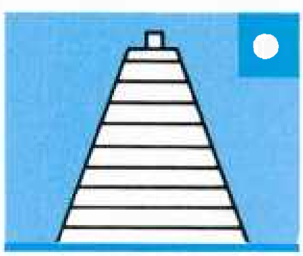


Passage for vessels with rafts - clearance less than 10 m

River beacons

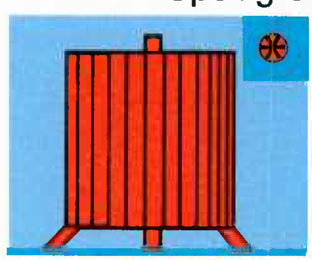


Right bank

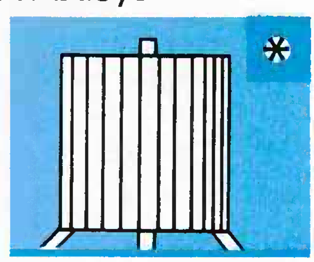


Left bank

Spoil ground buoys

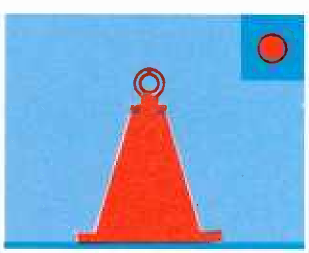


Right bank

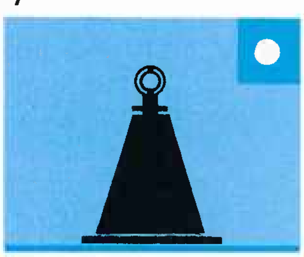


Left bank

Buoys

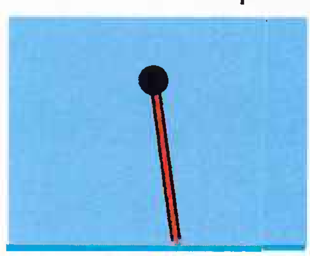


Right bank

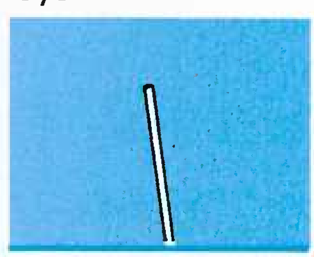


Left bank

Spar buoys

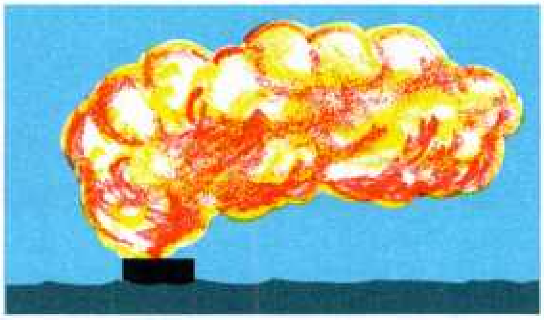
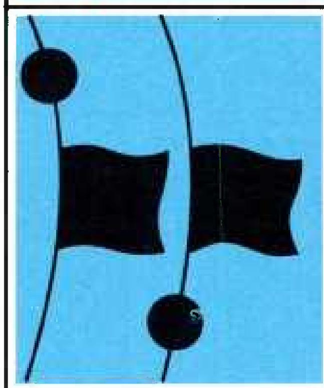
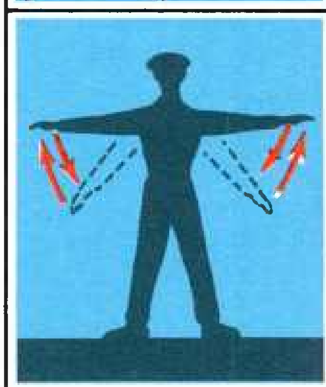


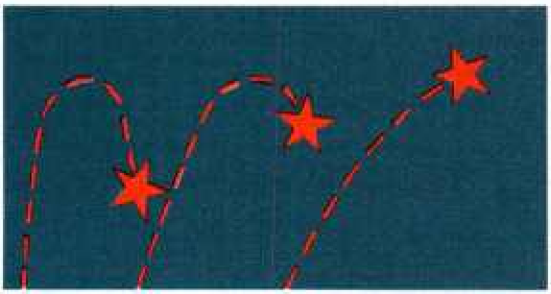
Right bank



Left bank

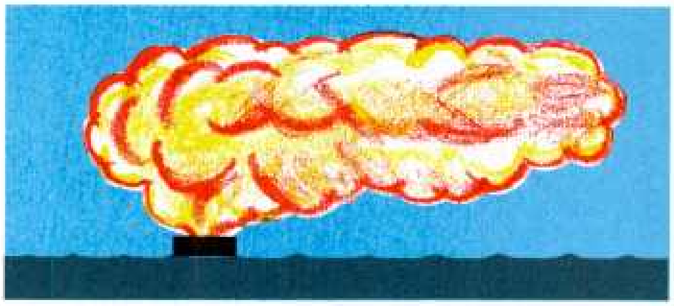
DISTRESS SIGNALS (INTERNATIONAL)

Type of Signal			Meaning of Signal
Daytime	 Releasing orange smoke	Firing guns or carrying out explosions at 1 minute intervals Continuous sound signals emitted by any fog signalling appliance	I am in distress and need help
	Or signal NC taken from the international code of signals	Or an SOS signal transmitted by means of a radiotelegraph system or some other signalling system	
	Or a sign consisting of a square flag with a ball placed below or above the flag	Or the word "Mayday" transmitted over the telephone	
	Or slow raising and lowering of stretched out arms		

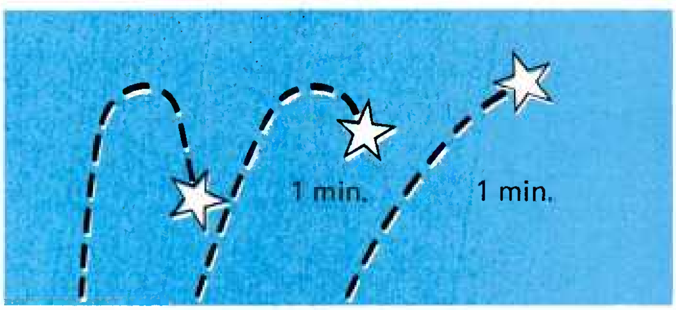
<table>
<tr><th colspan="3">Type of Signal</th><th>Meaning of Signal</th></tr>
<tr><td>Nighttime</td><td>
Flares or grenades which release red stars and which are fired one at a time at short intervals</td><td rowspan="4">Or a radiotelegraph distress signal; or a radiotelephone distress signal; or position indicating signals transmitted by emergency radio buoys</td><td rowspan="4">I am in distress and need help</td></tr>
<tr><td colspan="2"> Fire produced by igniting tar in a drum aboard ship</td></tr>
<tr><td colspan="2"> Or a red flare on a parachute</td></tr>
<tr><td colspan="2"> Or a red light</td></tr>
<tr><td colspan="4">NOTE: Signals may be displayed either simultaneously or one at a time. Nighttime signals may also be used in daytime or vice versa.</td></tr>
</table>

RESCUE SIGNALS (INTERNATIONAL)

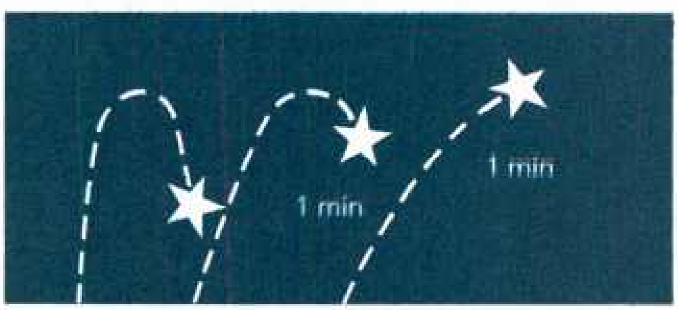
(a) Signals issued by rescue stations and marine rescue organizations to answer distress signals coming from ships and individuals

<table>
<tr><th colspan="2">Type of Signal</th><th>Meaning of Signal</th></tr>
<tr><td>Daytime</td><td>


Orange colored smoke signal

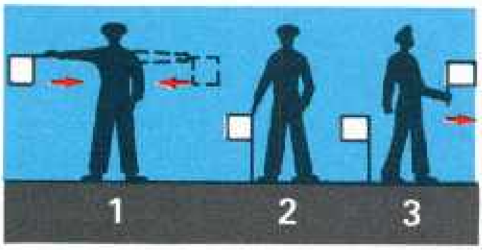


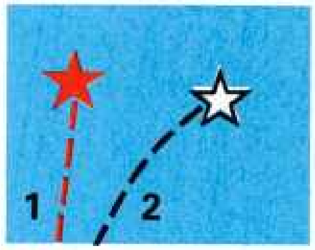
Or a combination-type sound and light signal consisting of three separate signals displayed at about 1 minute intervals
</td><td rowspan="2">We see you - assistance will be given as soon as possible

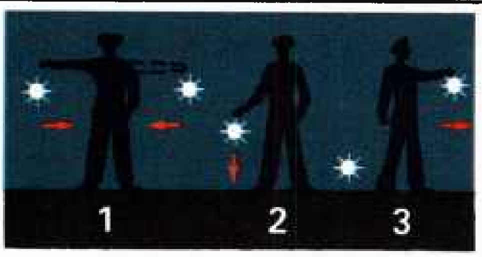
(Repetition of the signal does not change its meaning)</td></tr>
<tr><td>Nighttime</td><td>


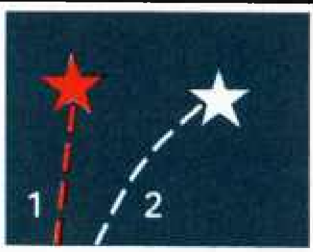
A white star flare consisting of three separate signals occurring at about 1 minute intervals
</td></tr>
<tr><td colspan="3">NOTE: Daytime signals may be displayed at night and vice verse, if necessary.</td></tr>
</table>

(b) Signals used for disembarking given to crews and individuals and to small ships in distress

<table>
<tr><th colspan="3">Type of Signal</th><th>Meaning of Signal</th></tr>
<tr><td>Daytime</td><td>

Horizontal motion with a white flag with the subsequent placement of the flag in the ground and moving a second flag in the direction of the desired disembarkation site</td><td>

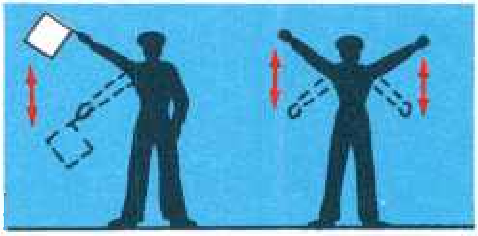
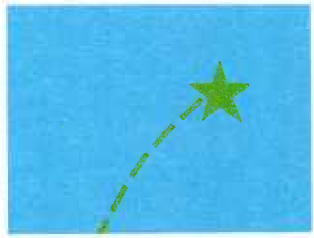
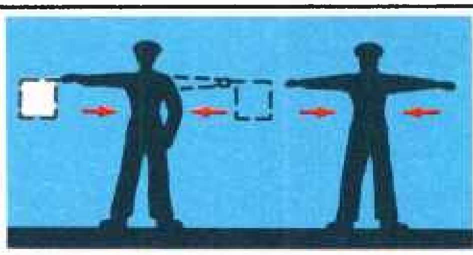
Or a red star signal displayed vertically and a white star signal displayed in the direction of the better disembarkation site</td><td rowspan="3">Disembarking is extremely dangerous here; a more favorable site is located in the direction indicated</td></tr>
<tr><td>Nighttime</td><td>

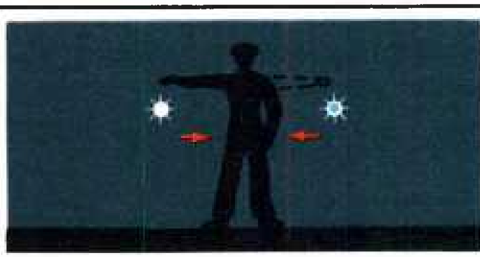
Horizontal motion with a white light or torch with the subsequent placement of the light (or the torch) in the ground and moving a second white light or torch in the suggested direction</td><td>

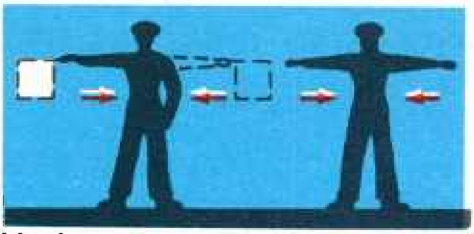
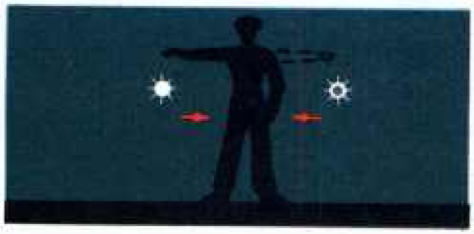
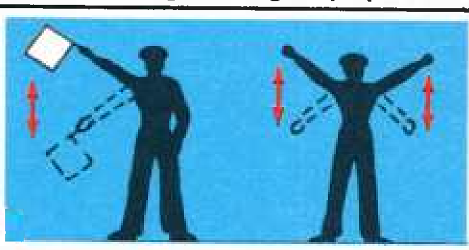
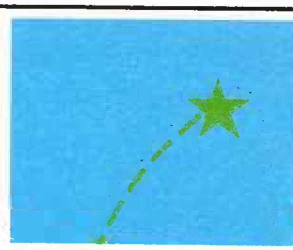
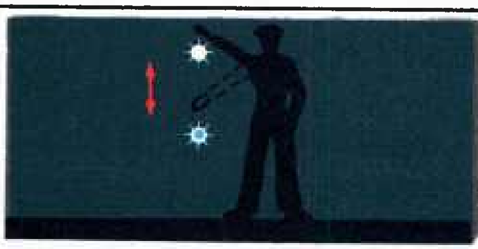
Or a red star signal displayed vertically and a white star signal displayed in the direction of the better disembarking site</td></tr>
<tr><td colspan="3">Or the transmission of letter S(...) and then letter R(.—.) if a better site for disembarking from a small ship in distress is located more to the right of that ship or the transmission of letter S(...) and then letter L(.—..) if a better site for disembarking from a small ship in distress is located more to the left of that ship</td></tr>
</table>

APPENDIX 10 (Cont'd)

SIGNALS USED WHEN EMPLOYING SHORE LIFESAVING GEAR

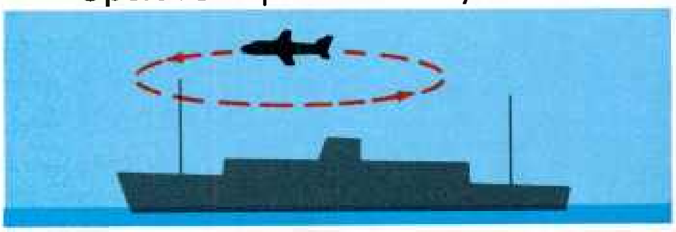
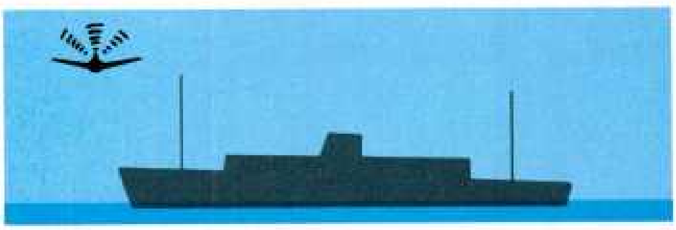
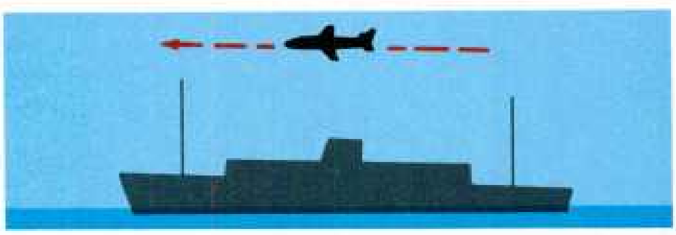
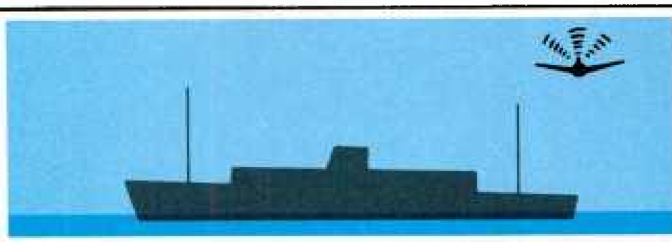
<table>
<tr><th colspan="3">Type of Signal</th><th>Meaning of Signal</th></tr>
<tr><td>Daytime</td><td>
Vertical motion with a white flag or motion of arms</td><td>
Or displaying a green star signal</td><td rowspan="2">In the general case the meaning is "Affirmative". In the special case the meaning is: "The rocket lifesaving line is secured"; "Block with the line is secured"; "The towing line is secured"; "The man is in the lifesaving ring"; "Haul away"</td></tr>
<tr><td>Nighttime</td><td>
Vertical motion with a white light or torch</td><td>
Or displaying a green star signal</td></tr>
<tr><td>Daytime</td><td>
Horizontal motion with a white flag or horizontal motion of stretched-out arms</td><td>
Or displaying a red star signal</td><td rowspan="2">In the general case the meaning is "Negative"

In the special case the meaning is "Ease off", "Stop hauling away"</td></tr>
<tr><td>Nighttime</td><td>
Horizontal motion with a white light or torch</td><td>
Or displaying a red star signal</td></tr>
</table>

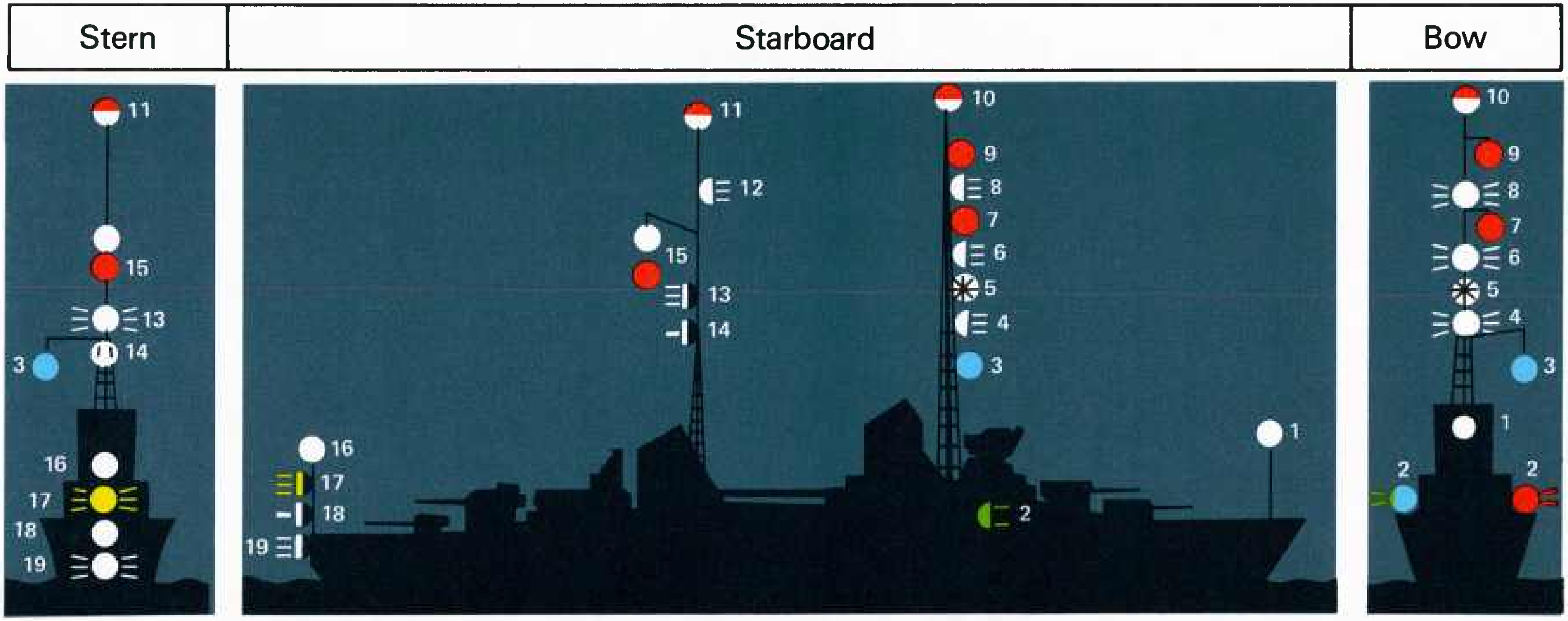
	Type of Signal		Meaning of Signal
Daytime	 Horizontal motion with a white flag or horizontal motion of outstretched arms	 Or displaying a red star signal	Disembarking is extremely dangerous here
Nighttime	 Horizontal motion with a white light or torch	 Or displaying a red star signal	
	Or transmitting letter S(...) by means of light or sound signalling equipment		
Daytime	 Vertical motion with a white flag or vertical motion of arms	 Or displaying a green star signal	Here is a better disembarkation site
Nighttime	 Vertical motion with a white light or torch	 Or displaying a green star signal	
	Or transmitting letter K(—.—) by means of light or sound signalling equipment		

NOTE: The direction indicating range may be displayed by placing a fixed light or torch at a level below that of the observer and along the line with the observer.

SIGNALS USED BY AIRCRAFT, ENGAGED IN SEARCH AND RESCUE OPERATIONS, TO GIVE TO THE SHIP THE BEARINGS OF SHIPS, AIRCRAFT OR INDIVIDUALS IN DISTRESS

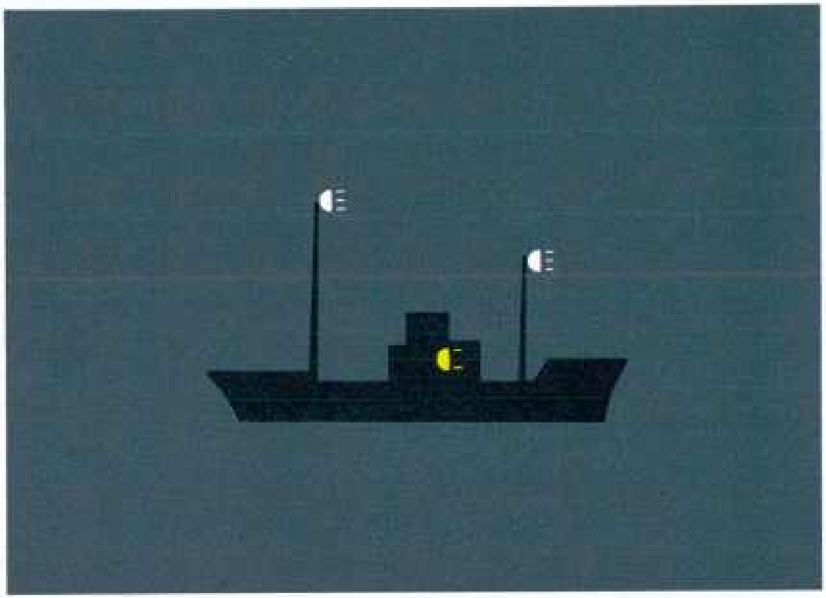
Type of Signal	Meaning of Signal
Operations performed by aircraft  Aircraft circles at least once over the ship  Aircraft crosses the courses of ship at low altitude while opening and closing the throttle valve or changing the propellor pitch  Aircraft flies in the direction to be followed by the ship	Aircraft gives to the ship the bearing of the aircraft or ship in distress (Repetition of the signal does not change its meaning)
 Aircraft crosses ship's wake at low altitude while opening and closing the throttle valve or changing the propellor pitch	Assistance is no longer required (Repetition of the signal does not change its meaning)

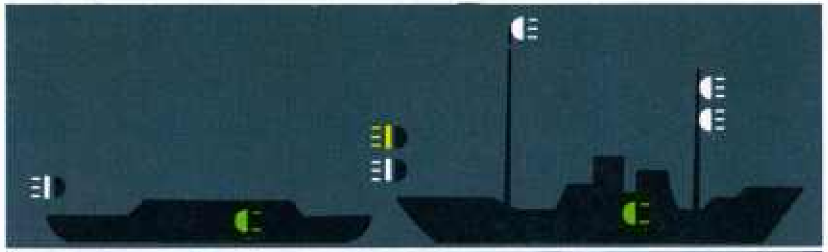
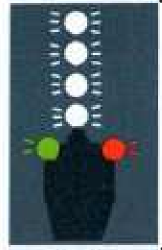
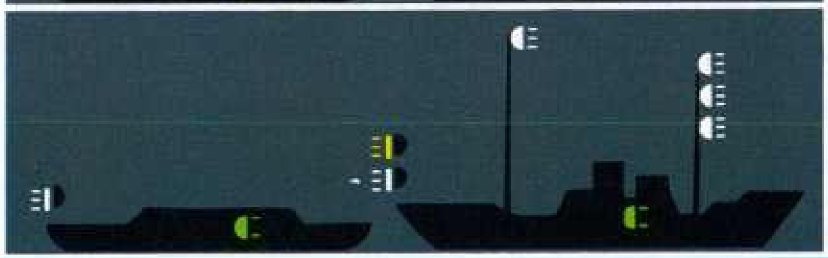
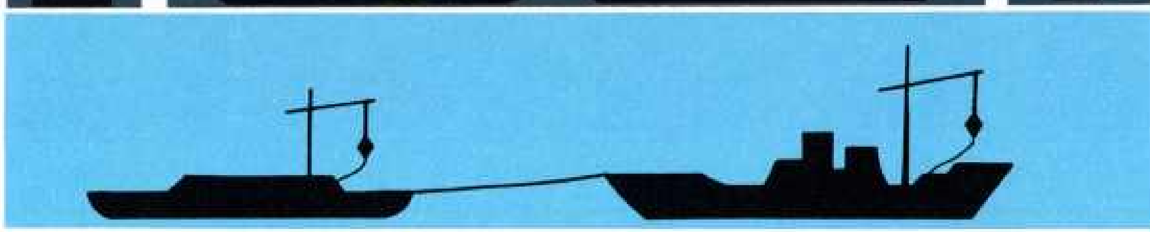
SHIP LIGHTS AND SHAPES

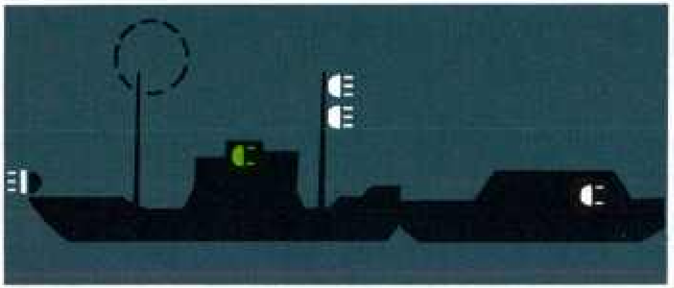
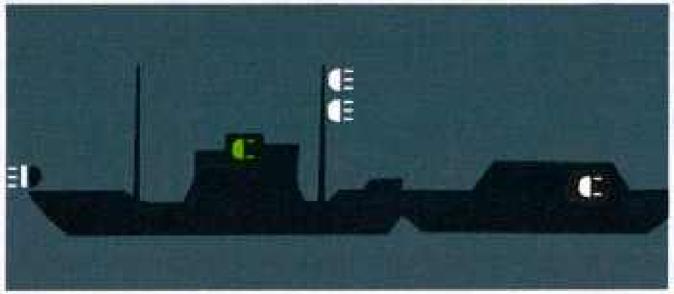
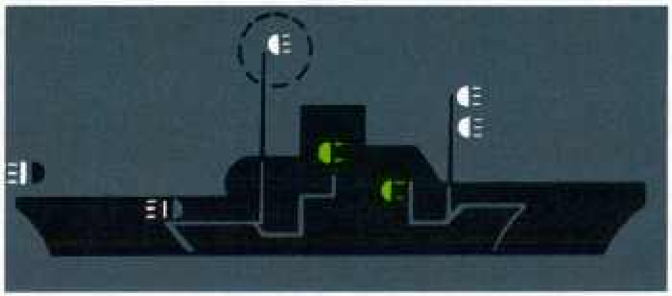
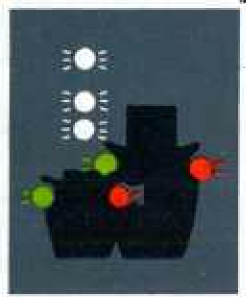
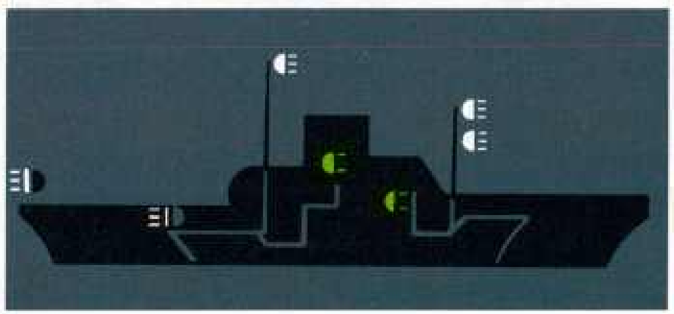
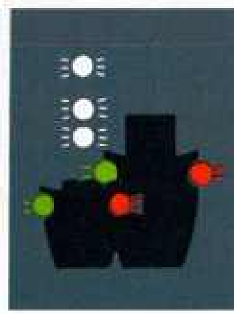


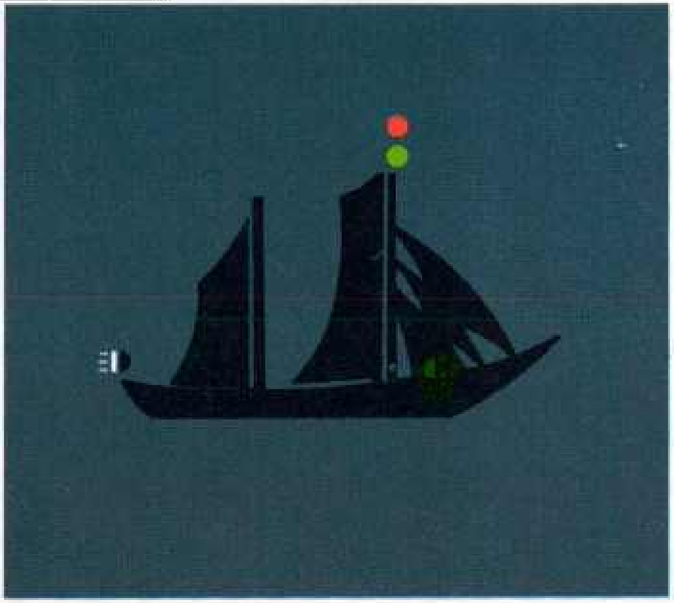
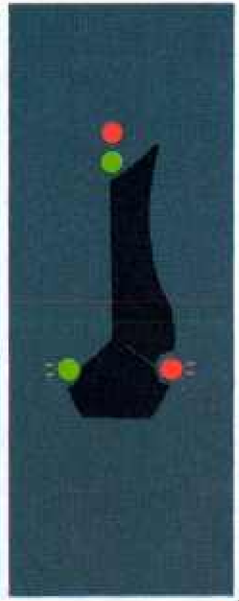
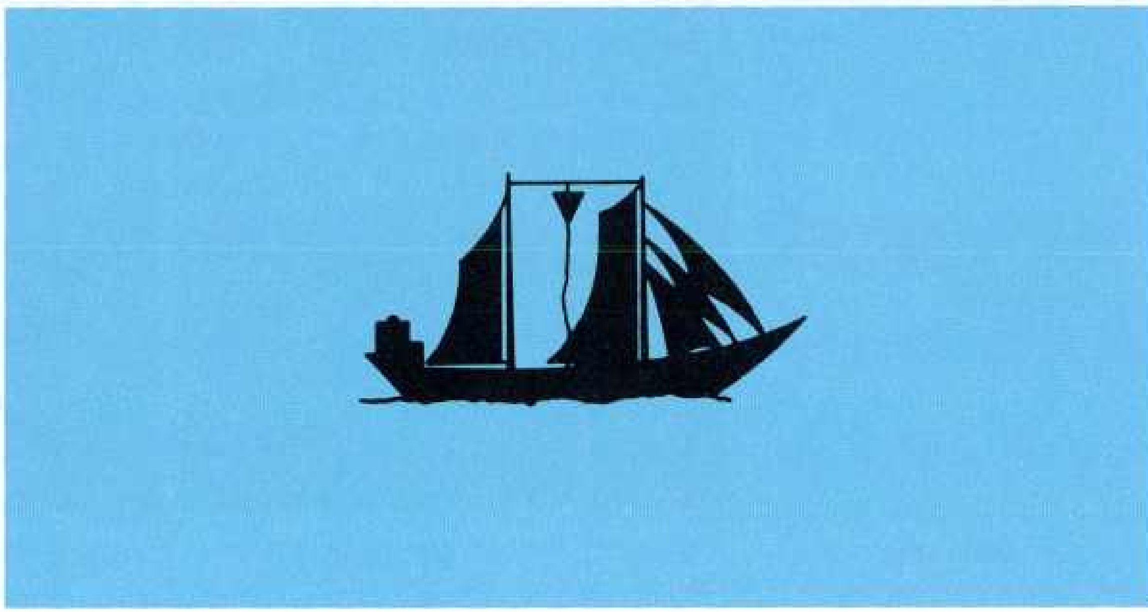
Lights of Warships (Arrangement and Characteristics)

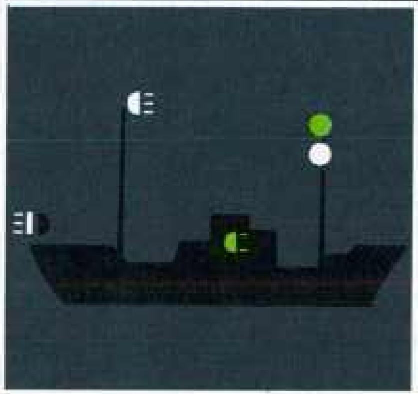
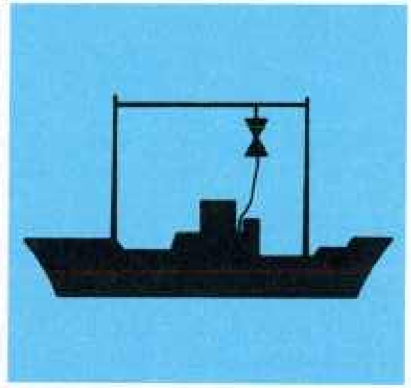
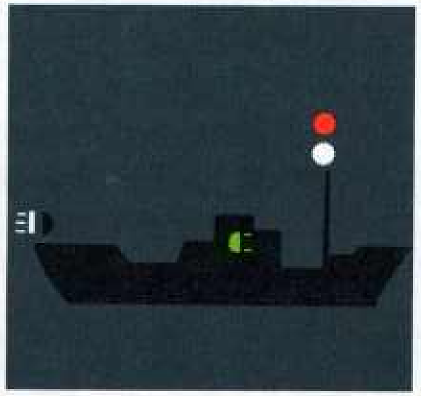
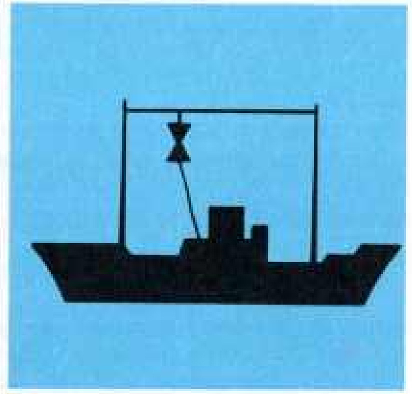
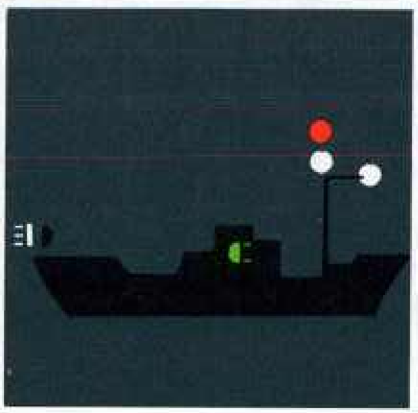
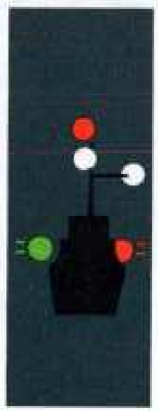
1. Bowlight, 360°, 3 miles
2. Sidelight, 112.5°, 1-3 miles
3. Duty light, 360°
4. Lower mastheat light, 225°, 2-6 miles
5. Maneuvering (Flashing) light, 360°, 5 miles
6. & 8. Towing lights, 225°, 2-6 miles
7. & 9. Emergency light, 360°, 2-3 miles
10. & 11. Truck lights, 360°
12. Upper masthead light, 225°, 2-6 miles
13. Flagship light, 135°
14. Upper tail light, 10°
15. Gaff lights, 360°, 3 miles
16. Stern anchor light, 360°, 3 miles
17. Towing light, 135°, 2-3 miles
18. Lower tail light, 10°
19. Sternlight, 135°, 2-3 miles
20. Notes: 1. The port view differs from that of the starboard only by the red color of the sidelight. 2. All-round lights (white, red, green, and yellow, 360°, 2-3 miles) and shapes, placed in frames are displayed in various combinations along a vertical line in the most visible area. 3. Lights and shapes with dashed lines around them are not mandatory.

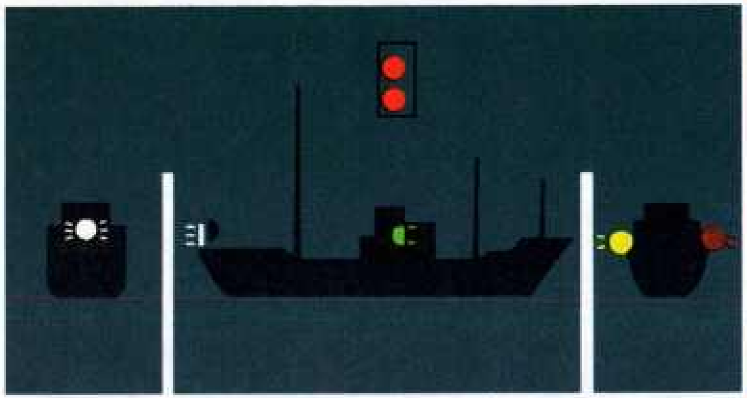
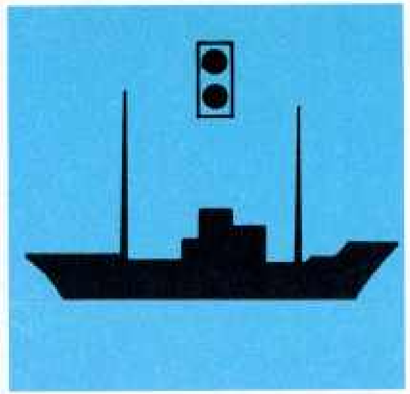
Stern	Starboard	Bow	Explanations
			Lights of power driven vessels underway Ship length, 50 m or more
			Ship length less than 50 m

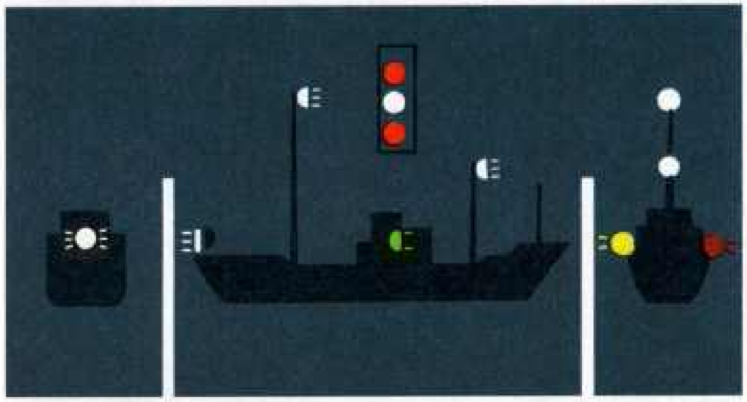
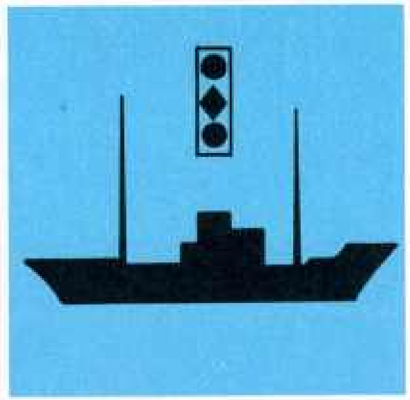
Stern	Starboard	Bow	Explanations
			Lights and shapes of towing and pushing vessels (Rule 24) Lights of towing power driven vessel less than 50 m in length (Rule 24a) Length of the tow less than 200 m
			Length of the tow more than 200 m
			Lights of towing power driven vessel 50 m in length or more (Rule 24a) Length of the tow less than 200 m
			Length of the tow more than 200 m
			In daytime. Length of the tow more than 200 m

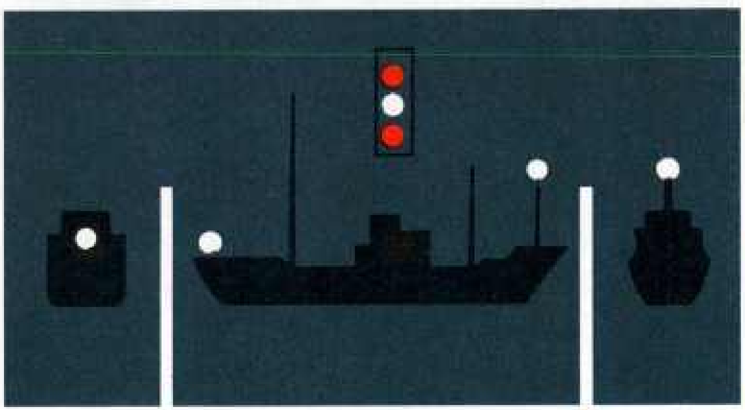
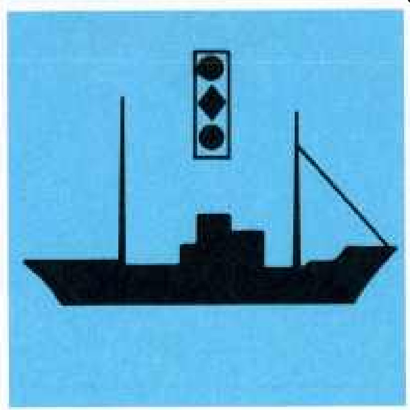
Stern	Starboard	Bow	Explanations
			Lights of a power drive vessel, pushing or towing alongside another vessel (Rule 24c) Length of pushing vessel less than 50 m
			Length of pushing vessel 50 m or more
			Length of towing vessel less than 50 m
			Length of towing vessel 50 m or more

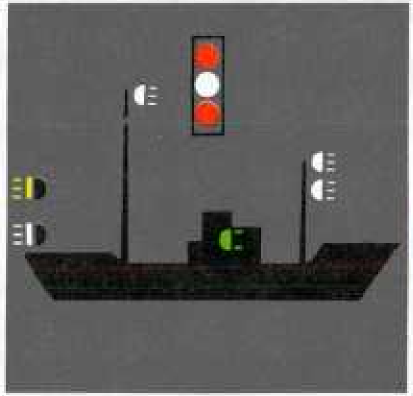
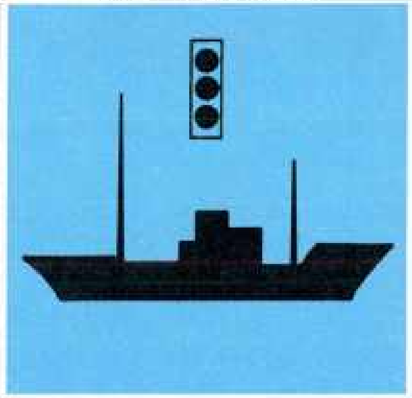
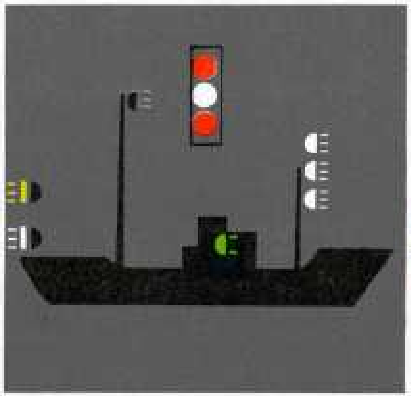
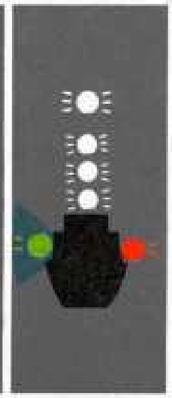
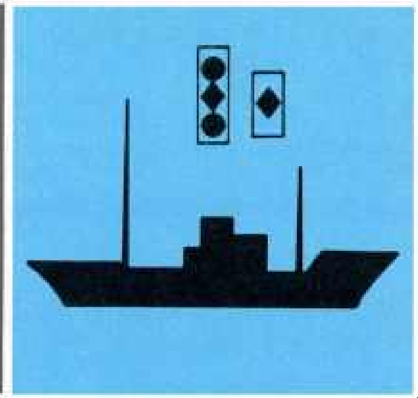
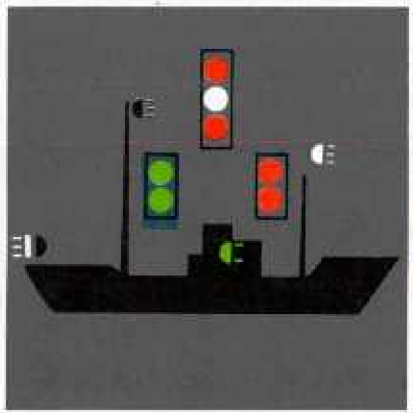
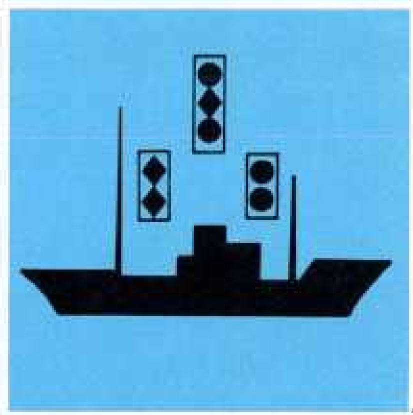
Stern	Starboard	Bow	Explanations
			Lights and shapes of a sailing vessel (Rule 25) Lights of an underway sailing vessel 12 m in length or longer (Rule 25a)
			In daytime vessels proceeding under sail and being propelled by machinery (Rule 25e)

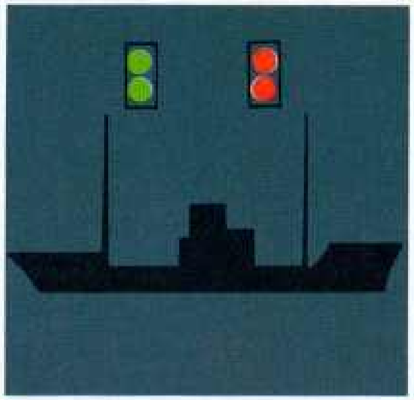
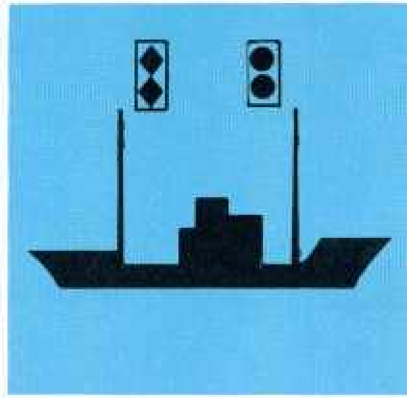
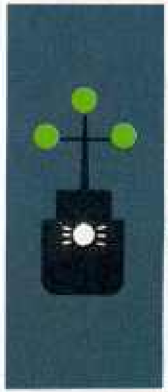
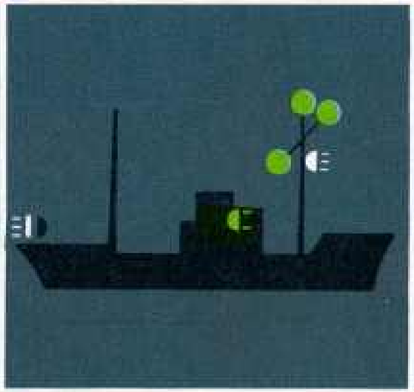
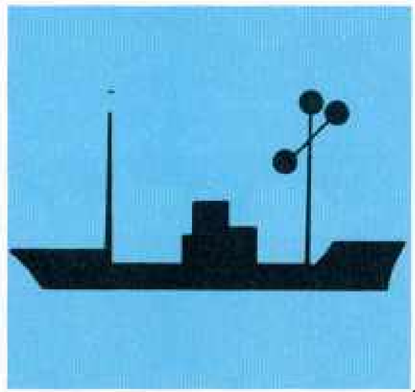
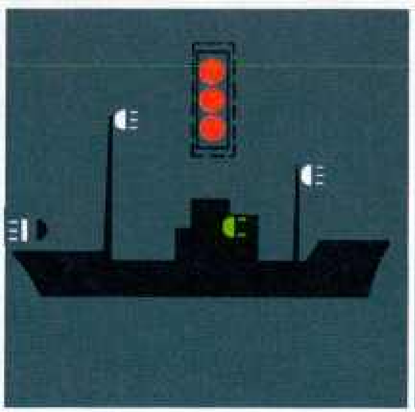
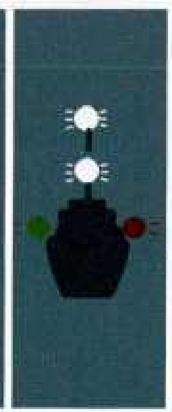
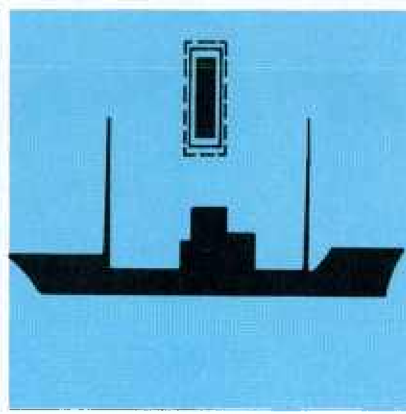
Stern	Starboard	Bow	Daytime	Explanations
				Lights and shapes of a fishing vessel (Rule 26) Lights and shapes of a fishing vessel engaged in trawling, i.e., dragging through the water of a dredge net (Rule 26b) Length of vessel 50 m or more
				Lights and shapes of a vessel engaged in fishing other than trawling (Rule 26c)
				Fishing tackle extends horizontally more than 150 m out to sea

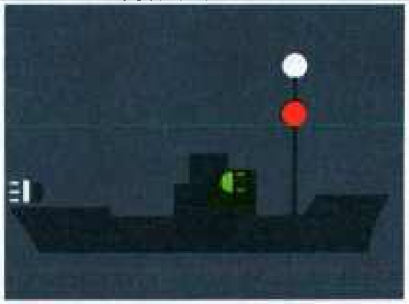
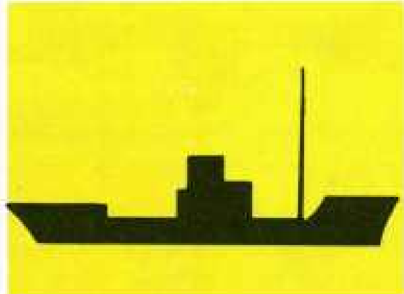
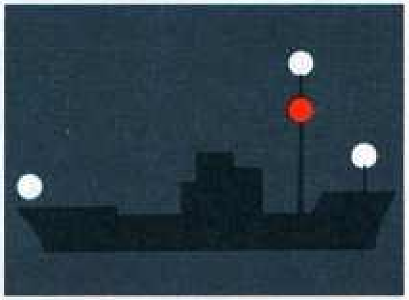
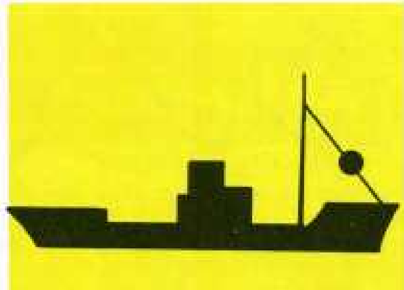
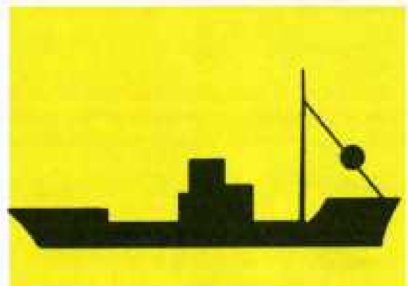
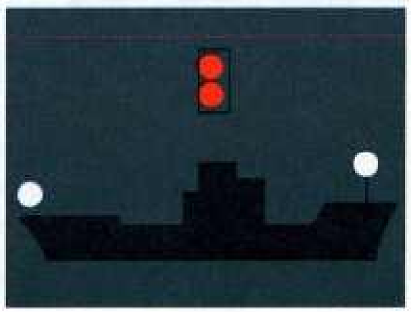
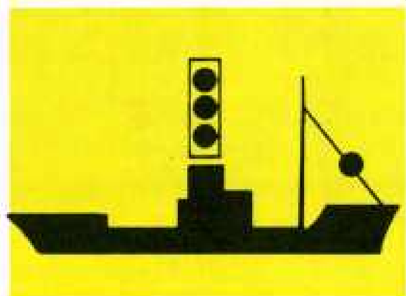
<table>
<tr><th>Stern</th><th>Starboard</th><th>Bow</th><th>Daytime</th><th>Explanations</th></tr>
<tr><td colspan="3"></td><td></td><td>Lights and shapes of a vessel not under command or restricted in her ability to maneuver (Rule 27)

Length of towing vessel 50 m or longer, length of tow greater than 200 m</td></tr>
<tr><td colspan="3"></td><td></td><td>Lights and shapes of a vessel restricted in her ability to maneuver, except a vessel engaged in minesweeping (Rule 27b)

Ship length 50 m or longer</td></tr>
<tr><td colspan="3"></td><td></td><td>At anchor</td></tr>
</table>

Stern	Starboard	Bow	Daytime	Explanations
				Lights and shapes of a vessel engaged in towing which renders her unable to deviate from her course (Rule 27c) Length of towing vessel 50 m or longer, length of tow greater than 200 m
				Lights and shapes of a vessel engaged in dredging or underwater operations, restricted in her ability to maneuver, and obstructing passage of another vessel (Rule 27d)
				Length of vessel 50 m or longer

Stern	Starboard	Bow	Daytime	Explanations
				At anchor
				Lights and shapes of a vessel engaged in minesweeping (Rule 27f) Length of ship less than 50 m
				Lights and shapes of a vessel constrained by her draft (Rule 28) Length of vessel 50 m or longer

Stern	Starboard	Bow	Daytime	Explanations
				Lights and shapes of a pilot vessel engaged in pilotage duty (Rule 29) Underway
				At anchor
				Lights and shapes of a vessel at anchor (Rule 30a)
				Lights and shapes of a vessel aground (Rule 30d)

NAVAL FLAGS AND PENNANTS OF THE USSR

Naval Ensign of the USSR

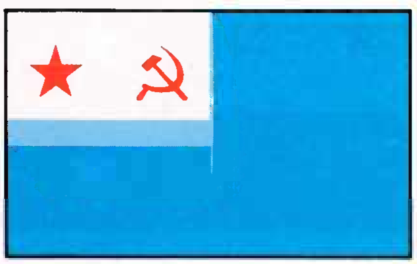
Guards' Naval Ensign of the USSR

Red-Banner Naval Ensign of the USSR

Decorated Naval Ensign of the Avrora Cruiser

Guards' Red Banner Naval Ensign of the USSR

Jack or Garrison Flag



Flag of Auxiliary Vessels of the Soviet Navy

Flag of Hydrographic Vessels of the Soviet Navy

Flag of Emergency Rescue Vessels of the Soviet Navy

Flag of the Supreme Commander of the USSR Armed Forces

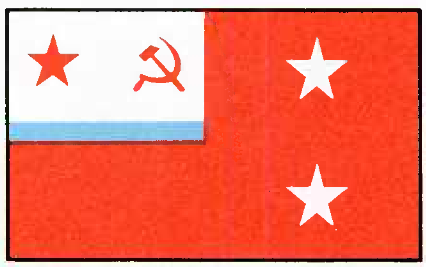
Flag of the USSR Minister of Defense

Flag of the Chief of General Staff of the USSR Armed Forces

Flag of the Commander in Chief of the USSR Navy

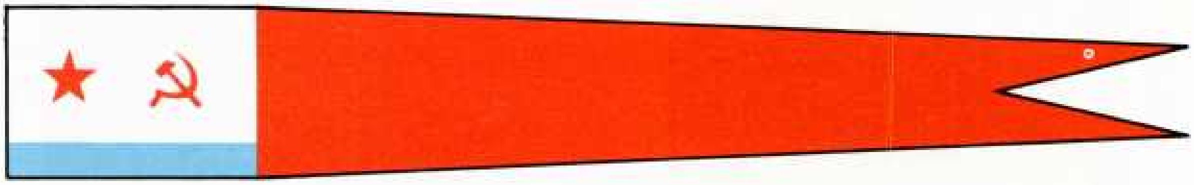
Flag of the Chief of the USSR Main Naval Staff

Flag of a Fleet Commander

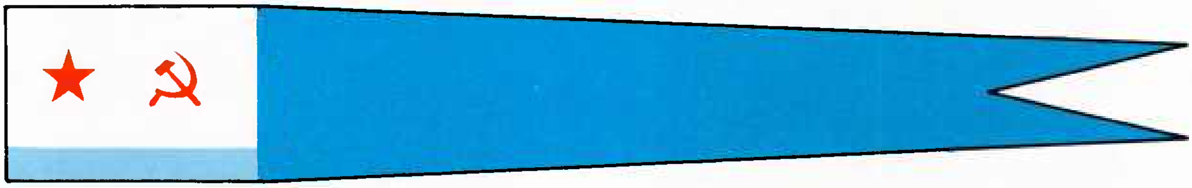


Flag of a Flotilla or Squadron Commander

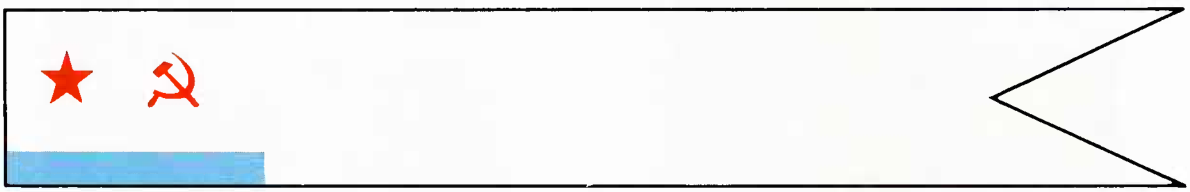
Flag of a Formation Commander



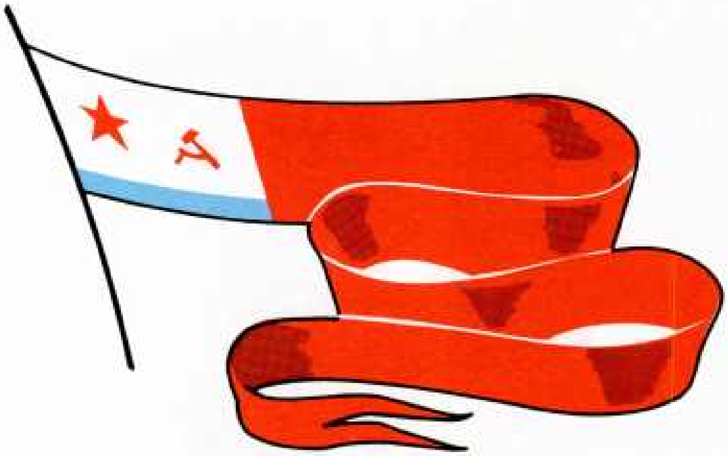
Broad Pennant of a Formation Commander



Broad Pennant of the Commander of a Division of Ships



Broad Pennant of the SOPA



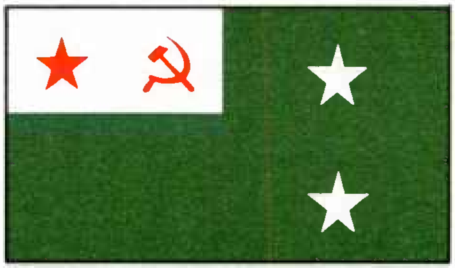
Naval Ship Pennant

Naval Ensign of Warships and Vessels of the Frontier Forces

Red Banner Naval Ensign of Warships and Vessels of the Frontier Forces

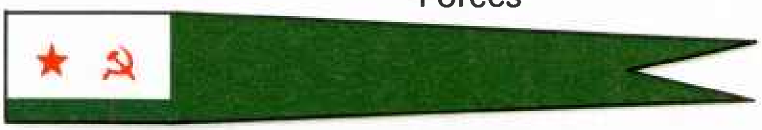
Flag of the Chairman of the Committee of State Security of the USSR Council of Ministers

Flag of the Commander of Frontier Forces, Committee of State Security of the USSR Council of Ministers



Flag of the Commander of the Frontier District Forces

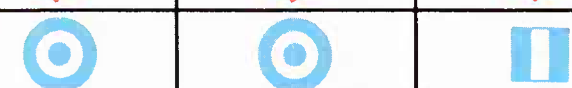
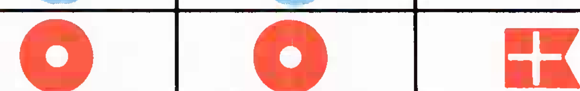
Flag of the Commander of a Formation of Ships of the Frontier Forces



Broad Pennant of the Commander of a Formation of Ships of the Frontier Forces

Pennant of Ships of the Frontier Forces

IDENTIFICATION MARKS OF AIRCRAFT OF CERTAIN FOREIGN NATIONS

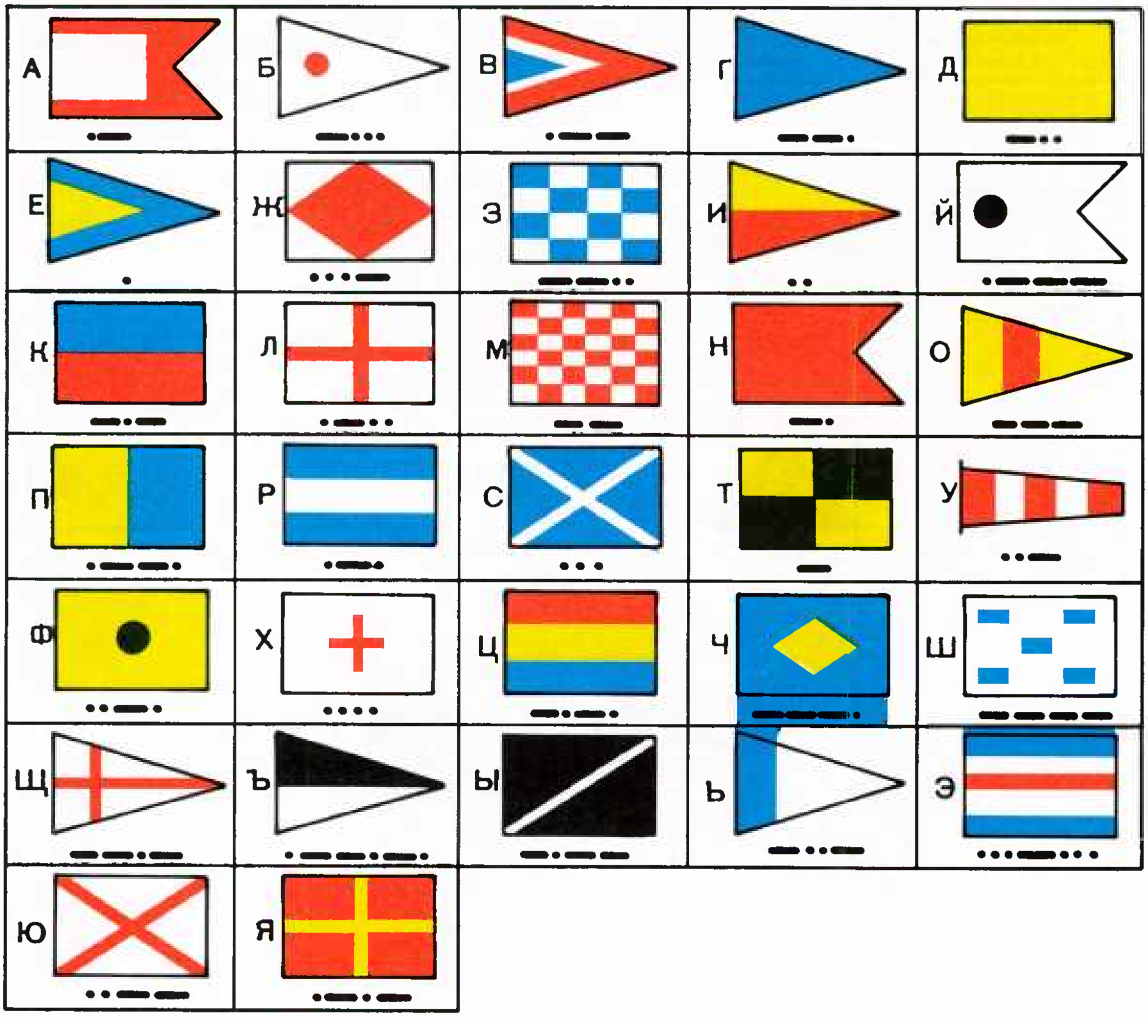
Country	On the Plane	On the Fuselage	On the Stabilizer
Australia			
Austria			
England			
Argentina			
Arab Republic of Egypt			
Belgium			
Bulgaria			
Brazil		—	
Hungary			—
GDR			
Greece			
Denmark			
India			
Indonesia			
Iran			
Spain			
Italy			—

APPENDIX 13 (Cont'd)

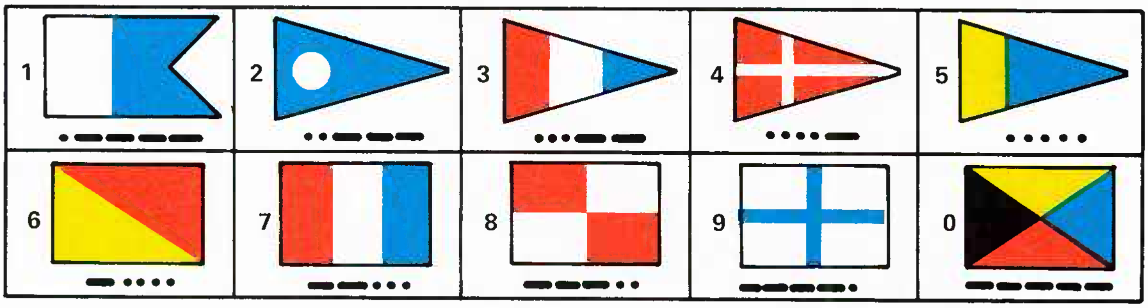
Country	On the Plane	On the Fuselage	On the Stabilizer
Canada			
China (CPR)			
Korea (KPDR)			—
Cuba		—	
Netherlands		—	
Norway			—
Pakistan			
Poland			
Portugal		—	
Romania			—
USA			—
Turkey			
FRG			
Finland			—
France			
Czechoslovakia			
Sweden			—
Yugoslavia			
South Korea			—
Japan			—

FLAGS OF THE USSR NAVAL CODE OF SIGNALS

ALPHABET FLAGS

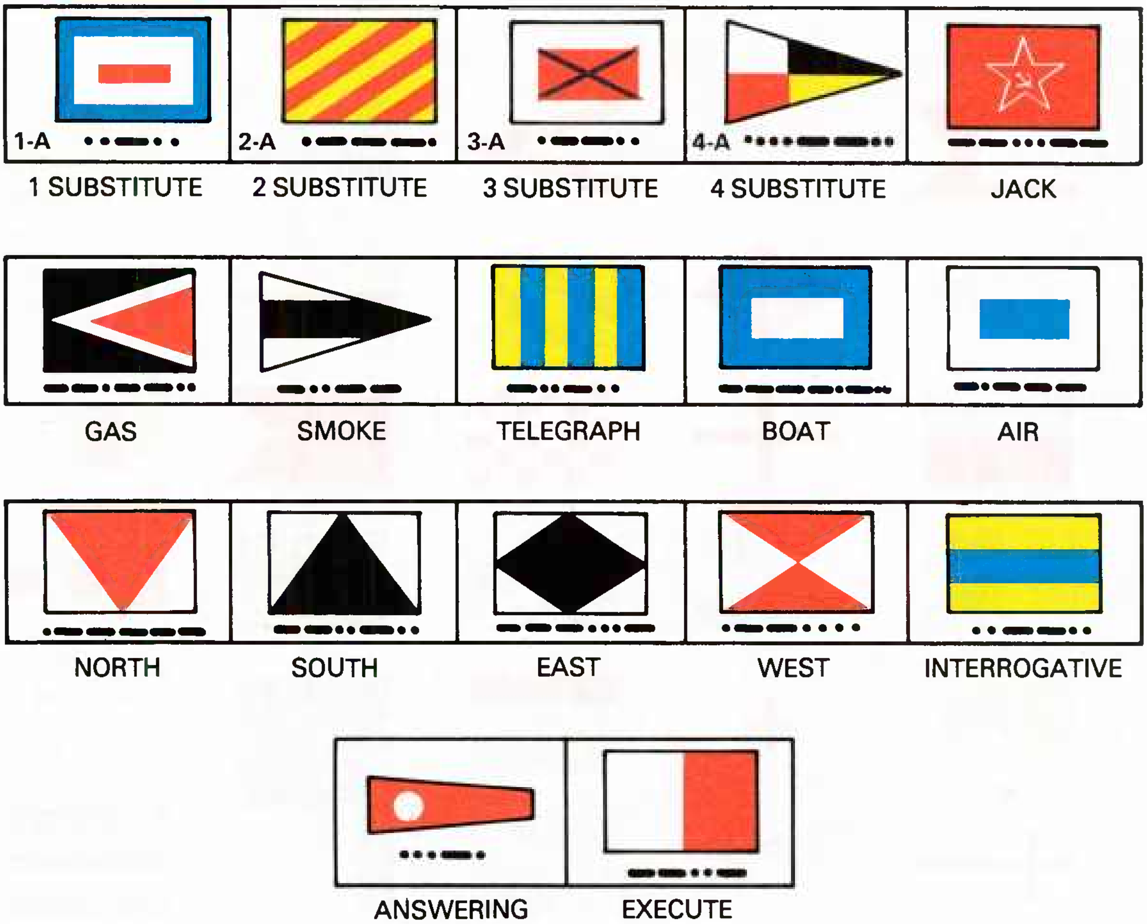


NUMERAL FLAGS

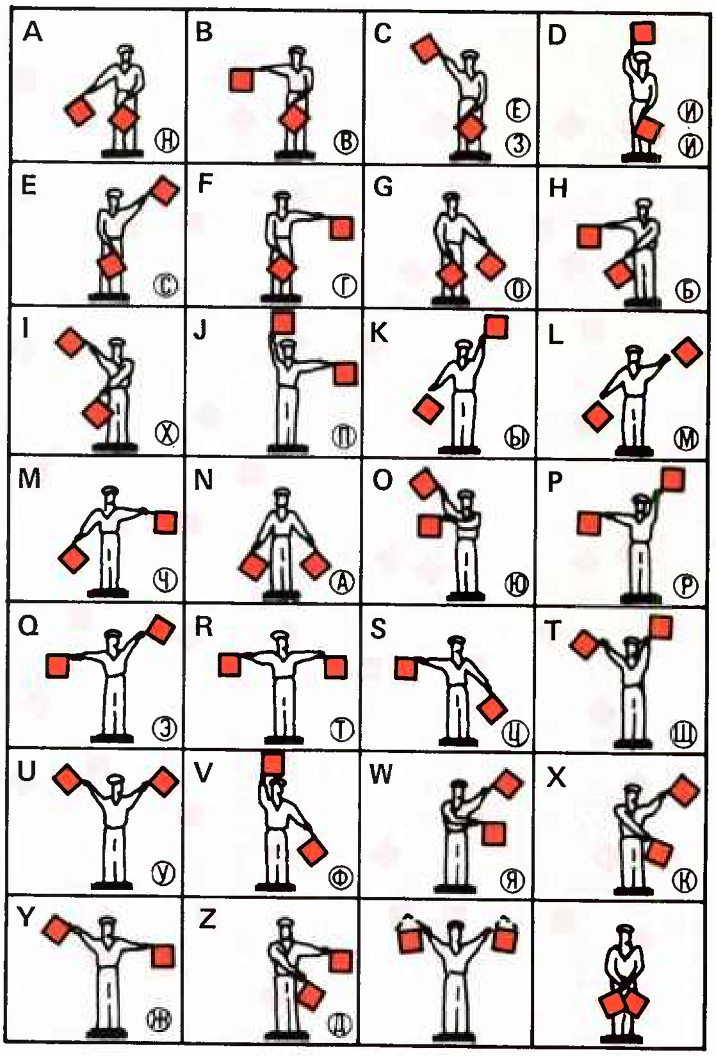


APPENDIX 14 (Cont'd)

SUBSTITUTE AND SPECIAL FLAGS

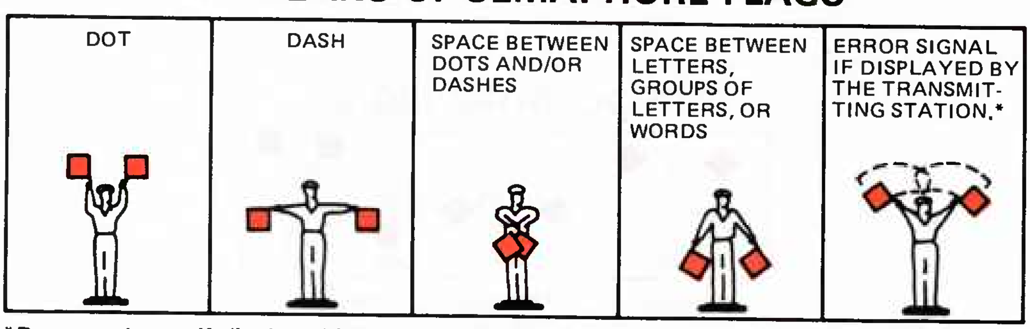


INTERNATIONAL SEMAPHORE ALPHABET



NOTE: Circles contain international semaphore letters transliterated with the letters used in the Russian semaphore alphabet. The numerator shows Latin letters and the denominator the corresponding letters in the Russian alphabet.

TELEGRAPH SIGNS TRANSMITTED BY MEANS OF SEMAPHORE FLAGS



*Repeat, please, if displayed by the receiving station